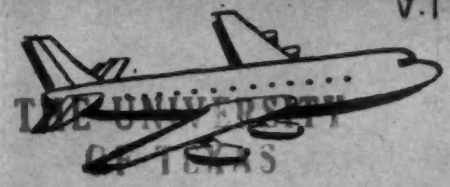
v.1 #2



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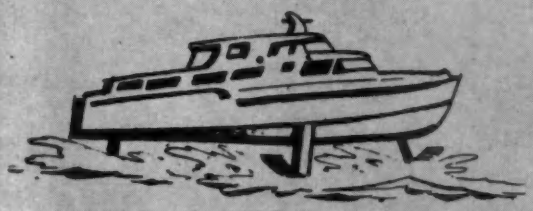
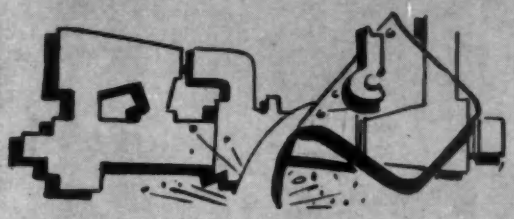
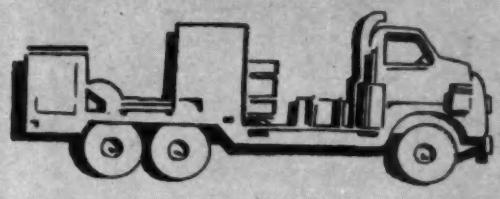
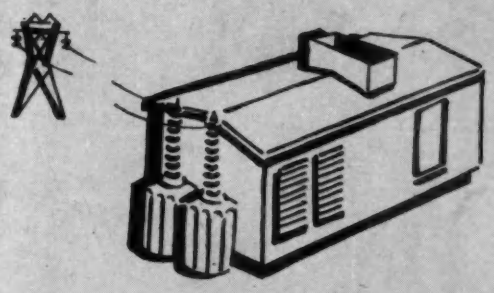
MARCH-APRIL 1960

GAS TURBINE









5 GT

FIFTH ANNUAL GAS TURBINE CONFERENCE

. . . from 800° Fahrenheit

. . . to 65° below zero

Environmental testing helps develop dependable Woodward Gas Turbine Fuel Controls

The high temperatures encountered with supersonic speeds are carefully simulated in Woodward's newest environmental testing facilities.

Here, complete fuel controls for jet engines are thoroughly tested in ambient temperatures up to 500° with fuels heated to 400° and hydraulic fluids up to 600°. The probe of the control's temperature sensor is checked at 800° ambient temperature.

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It's all part of Woodward's continuing technological progress in developing the best possible governors and fuel controls for modern prime movers.

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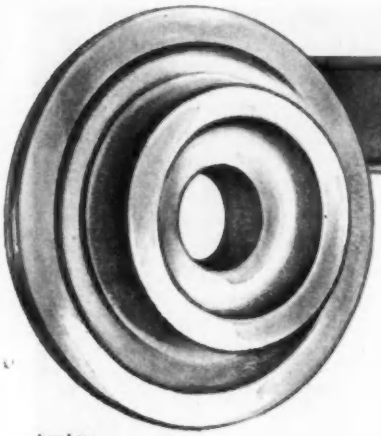
WORLD'S OLDEST AND LARGEST MANUFACTURER OF HYDRAULIC GOVERNORS EXCLUSIVELY

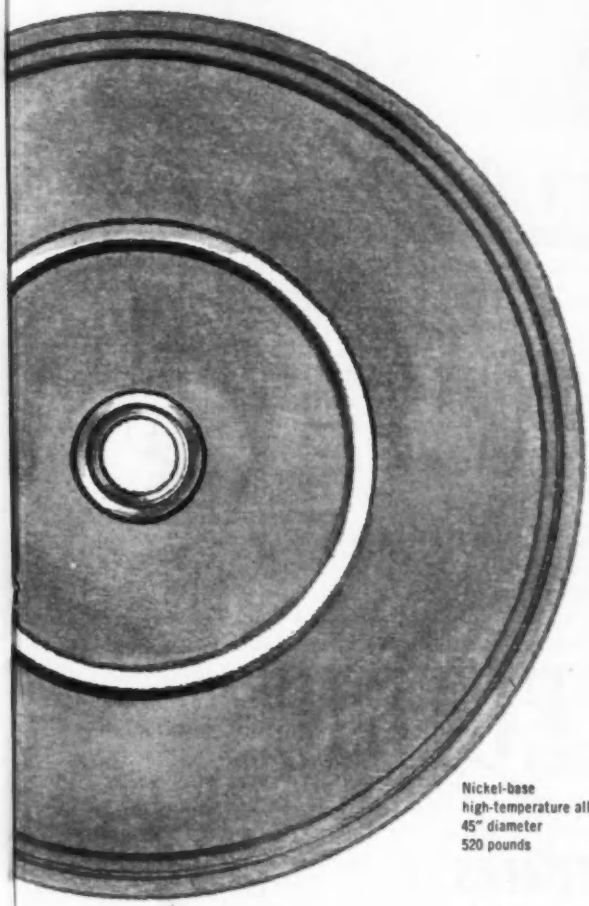


Iron-base
high-temperature alloy
21½" diameter
244 pounds

FORGED

Titanium
24½" diameter
191 pounds

To speed the progress of gas turbine development

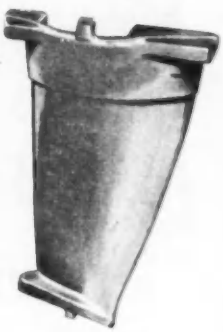


Nickel-base
high-temperature alloy
45" diameter
520 pounds

For applications ranging from automotive to aircraft propulsion, Wyman-Gordon is the world's largest producer of forged components for the gas turbine industry—turbine wheels, compressor discs, blades and vanes, for stationary turbines, nuclear installations, aircraft and missiles.

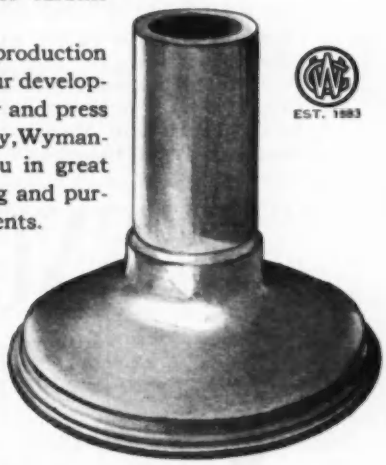
Wyman-Gordon's production experience includes forgings of a wide range of metals from low-alloy high-strength steels—titanium—intermediate temperature alloys—to the super-nickel-base alloys and refractory metals. *Guaranteed minimum properties* assure improved performance and dependability, and enable designers constantly to raise their sights and increase turbine capabilities.

With unexcelled research and production laboratories to concentrate on your development problems and with hammer and press capacity unequalled in the country, Wyman-Gordon is prepared to serve you in great depth at the design, engineering and purchasing stages of your requirements.



Titanium
15½" length

EST. 1883



High-strength steel
19" diameter
143 pounds

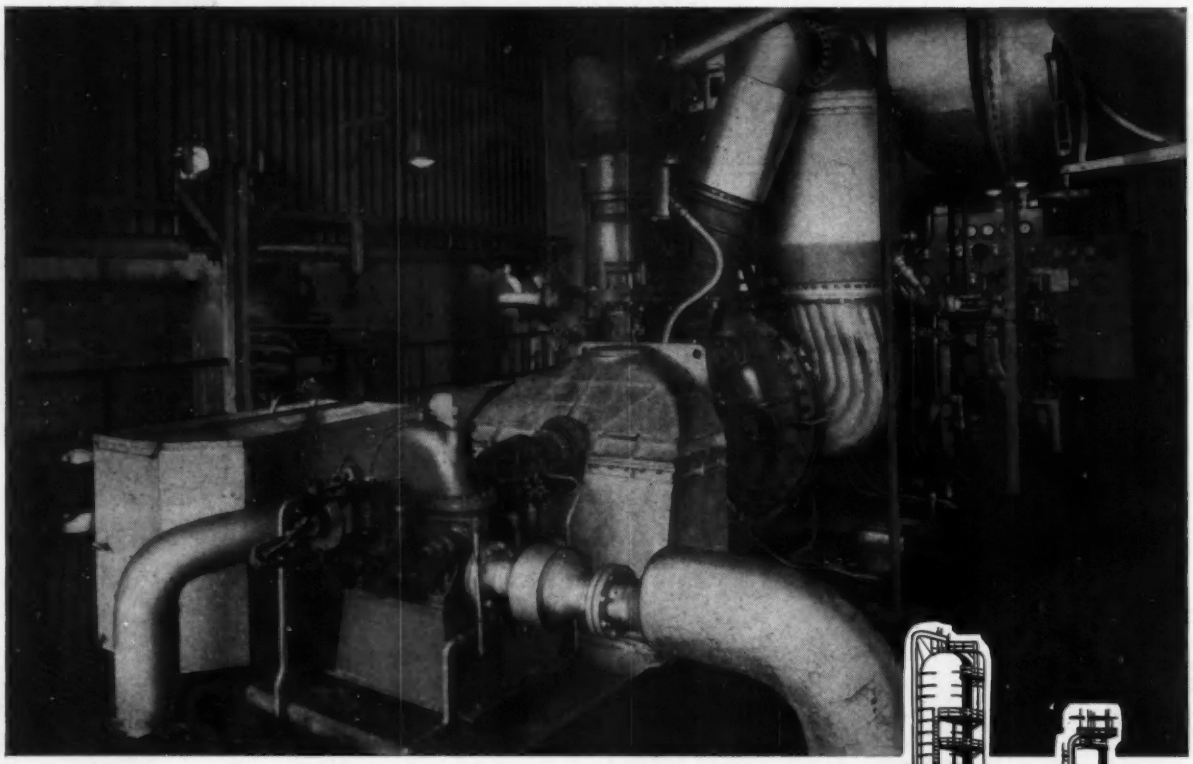
WYMAN-GORDON

FORGINGS

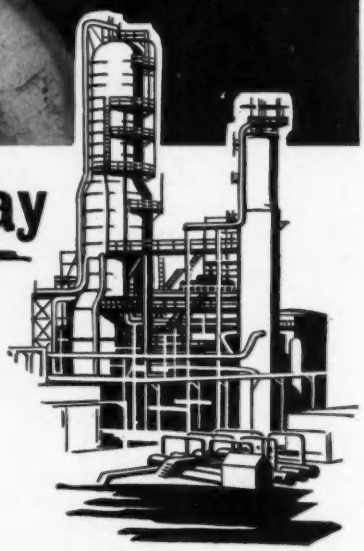
of Aluminum Magnesium Steel Titanium . . . and Beryllium Molybdenum Columbium and other uncommon materials

HARVEY ILLINOIS — WORCESTER MASSACHUSETTS — DETROIT MICHIGAN

GRAFTON MASSACHUSETTS — FRANKLIN PARK ILLINOIS — LOS ANGELES CALIFORNIA — FORT WORTH TEXAS



On duty 24 hours every day with Esso



This 'ENGLISH ELECTRIC' gas turbine operates continuously for twenty-four hours every day in the Esso petro-chemical plant at Fawley Refinery in England—without a standby.

It is direct-coupled to a propylene refrigeration compressor on the butadiene extraction unit and delivers 2,625 h.p. to the compressor coupling at a shaft speed of 7,500 r.p.m. Waste heat from the turbine is used to raise 18,000 lb/hr of low pressure steam at 125 lb. gauge, for general refinery services.

A model depicting a similar engine which is one of two now being supplied to Oil India for India's first gas turbine generating station will be on display this March at the A.S.M.E. Gas Turbine Conference at Houston, Texas (booths 34 and 35).

'ENGLISH ELECTRIC'

LONG-LIFE

industrial gas turbines

from 2,300 h.p. (1,600 kW)

ENGLISH ELECTRIC EXPORT AND TRADING COMPANY LIMITED, 750 THIRD AVENUE, NEW YORK 17, N. Y.
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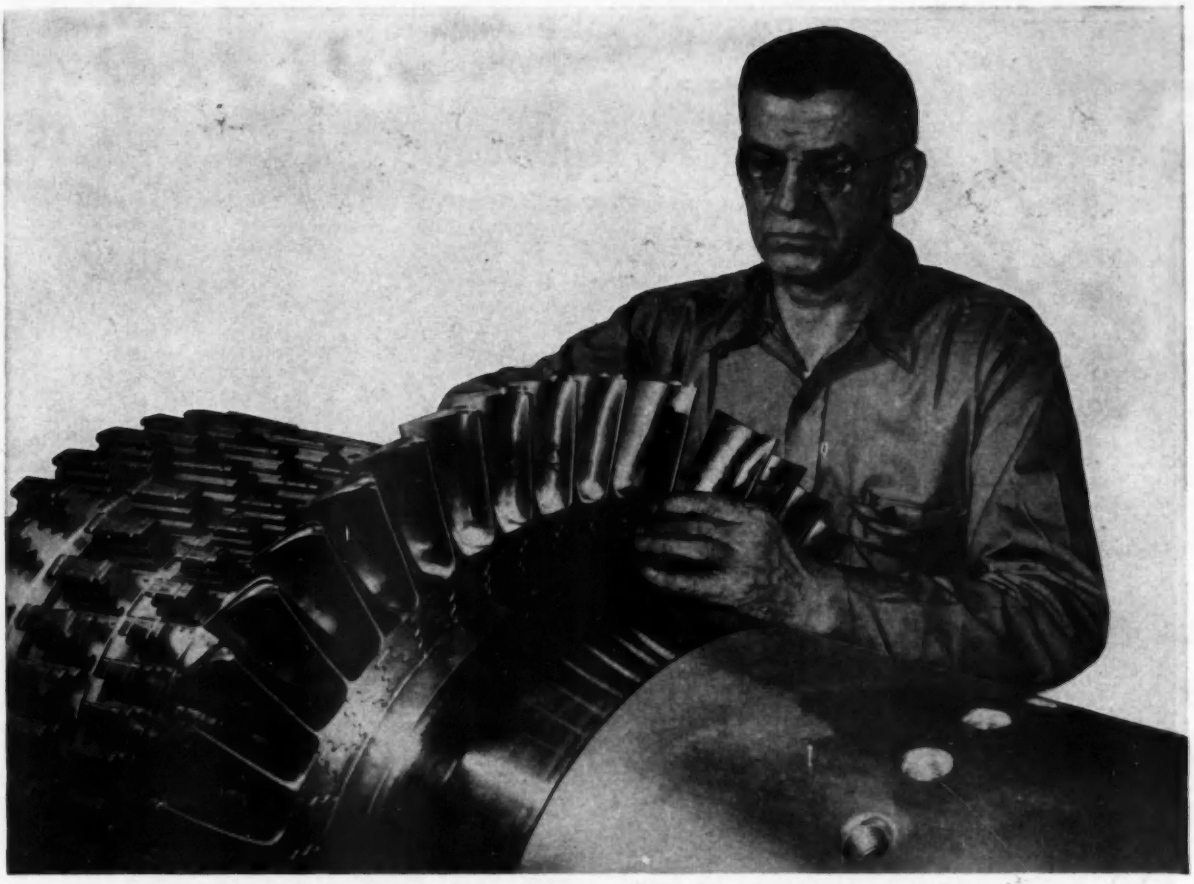

Conquering Heat, Erosion and Corrosion. Alloys containing Nickel give outstanding performance in vital components of gas turbines. In rotor section shown here, interlocking discs are held together by heat-resisting alloy bolts. Special high-temperature alloy blades fit into pine-tree grooves machined in the discs.

What's your special problem with high-temperature performance?

Perhaps INCO can help you solve it

Are you getting all you want out of metals that encounter temperatures above 1000°F?

Are you looking for better stress-to-rupture time? Improved resistance to thermal shock? Higher creep strength with good tensile properties and resistance to oxidants at design T_1?

Basic to the solution of materials-selection problems in the high-temperature area is a good central source of comparative data.

Thanks to research programs carried on by Inco's High-Temperature Engineering Service, we offer you a fund of valuable information. It includes design and engineering data on load carrying, resistance to corrosion and scaling, and other relevant information on performance of materials at high temperatures.

We will gladly share this experience with you . . . data that will help you select the most practical materials for high-temperature service in the equipment you design, build or maintain. Simply outline your problem in a brief note to Inco Application Engineering.

Visit the INCO booth

at the 5th Annual
Gas Turbine Conference
and Exhibition
Houston, Texas, *March 7-8-9.*

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N.Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Union Pacific's new and mighty locomotive crests Sherman Hill, Wyoming, with a heavy load.

WORLD'S MOST POWERFUL LOCOMOTIVE SPEEDS FREIGHT ECONOMICALLY WITH BENDIX FUEL AND IGNITION SYSTEMS

This is the world's mightiest self-powered locomotive at work. On level track, it can pull 735 fully loaded freight cars—a train more than seven miles long! Its two engines—an auxiliary diesel engine and a gas-turbine power plant—depend on Bendix fuel injection and ignition systems to help keep its mighty power flowing smoothly and efficiently.

This new gas turbine-electric locomotive, built by General Electric for Union Pacific, is designed to haul freight faster and more economically. It burns less expensive "residual" fuel—a thick, viscous substance with a heavy tar content which must be heated before it will flow freely.

The Bendix ignition system fires this low-volatile fuel as efficiently as volatile gasoline is ignited in your automobile engine. The Bendix fuel injection system is used in the auxiliary diesel engine, which also furnishes power for "yard" movement of the locomotive.

General Electric has been an important builder of locomotives for more than 65 years. To be selected as the supplier of fuel injection and ignition equipment by G.E. for the mightiest locomotive they have ever built, is truly one of the finest tributes that could be paid to the all around efficiency of Bendix equipment.

It is equally impressive that whenever exceptional performance, complete dependability and operating economy are the requirements, diesel engine manufacturers in increasing numbers are turning to Bendix for their fuel injection and ignition requirements.

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GAS TURBINE

VOLUME 1, No. 2, MARCH-APRIL, 1960

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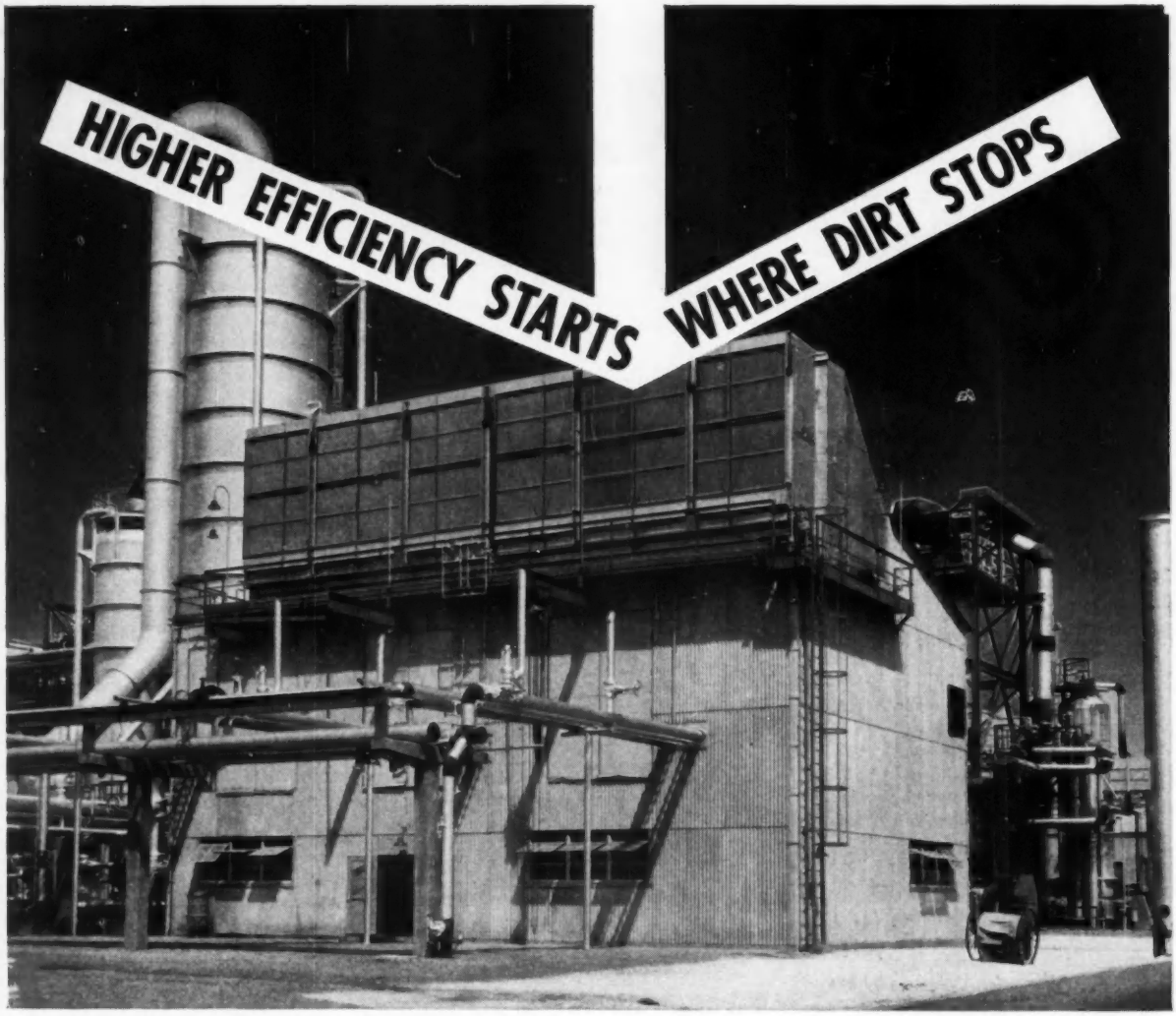


AAF cleans and cools intake air, helps boost petrochemical output

At Odessa Budadiene Co., Odessa, Texas, they're using the hot exhaust from two gas turbines to regenerate catalysts in the manufacture of budadiene.

A combination of MULTI-DUTY automatic, self-cleaning filters and Amer-Kool evaporative coolers assures clean, cool intake air for both 8500-HP turbines. The automatic intake filters operate continuously, while the evaporative coolers are operated only when ambient temperatures necessitate cooling the air for increased turbine output.

Whether your operation is in a hot and dusty desert, a temperate region, or the Arctic — whether the application is one of process or pumping — whether your station is automatic or attended, portable or stationary — AAF has air filtration equipment *engineered* to match your requirements!

For information on AAF's complete line of BETTER AIR products for engines and compressors, write today for Bulletin 150. Address: Mr. Robert Moore, American Air Filter Co., Inc., 490 Central Ave., Louisville, Kentucky.

AAF American Air Filter

BETTER AIR IS OUR BUSINESS

EDITORIALLY SPEAKING

Put the gas turbine across . . .

Back in 1944, Dr. Sanford A. Moss of General Electric made the statement to Kenneth Salisbury and me, "You younger men have got to put the gas turbine across . . . I've tried three times and failed." Dr. Moss did not fail. He and the other pioneers who have passed on laid the groundwork on which this generation can build and succeed. If there is any validity in the law of conservation of energy, none of the work of the early leaders is lost—it is a threshold from which the many thousands, earnestly and sincerely working to make the gas turbine more successful, can proceed. And there are thousands. They can be found in industry, in the rosters of the technical societies both here and abroad. The Gas Turbine Power Division of ASME alone has close to 5000 men who have signified their interest in the gas turbine field. Dr. Moss and others of his time were dedicated men. As a mark of recognition, as an indication of the appreciation of their many contributions, we would like to dedicate GAS TURBINE to the proposition of helping make their dreams a reality. To do so we must dedicate our efforts to serving all those who are now carrying the ball—those who know what gas turbines can do . . . who have already placed the gas turbine in the many applications across the world . . . who are finding new and important jobs for them to do daily. So in a final sense we *dedicate* GAS TURBINE *to the job of helping today's industry to "put the gas turbine across."*

R. Tom Sawyer

Gas turbines show their breeding

BROWN BOVERI

By R. L. Steer, Project Engineer, Brown Boveri Corp.

Brown Boveri gas turbines have the "solid" look of steam turbines. The casings are machined castings. The rotor shafts are large. Bearings and other parts are easily accessible. Each turbine has a single, rugged combustion chamber.

This family resemblance comes naturally. Brown Boveri gas turbines were designed from the start for continuous stationary service . . . in contrast to lightweight units adapted from aircraft engine designs.

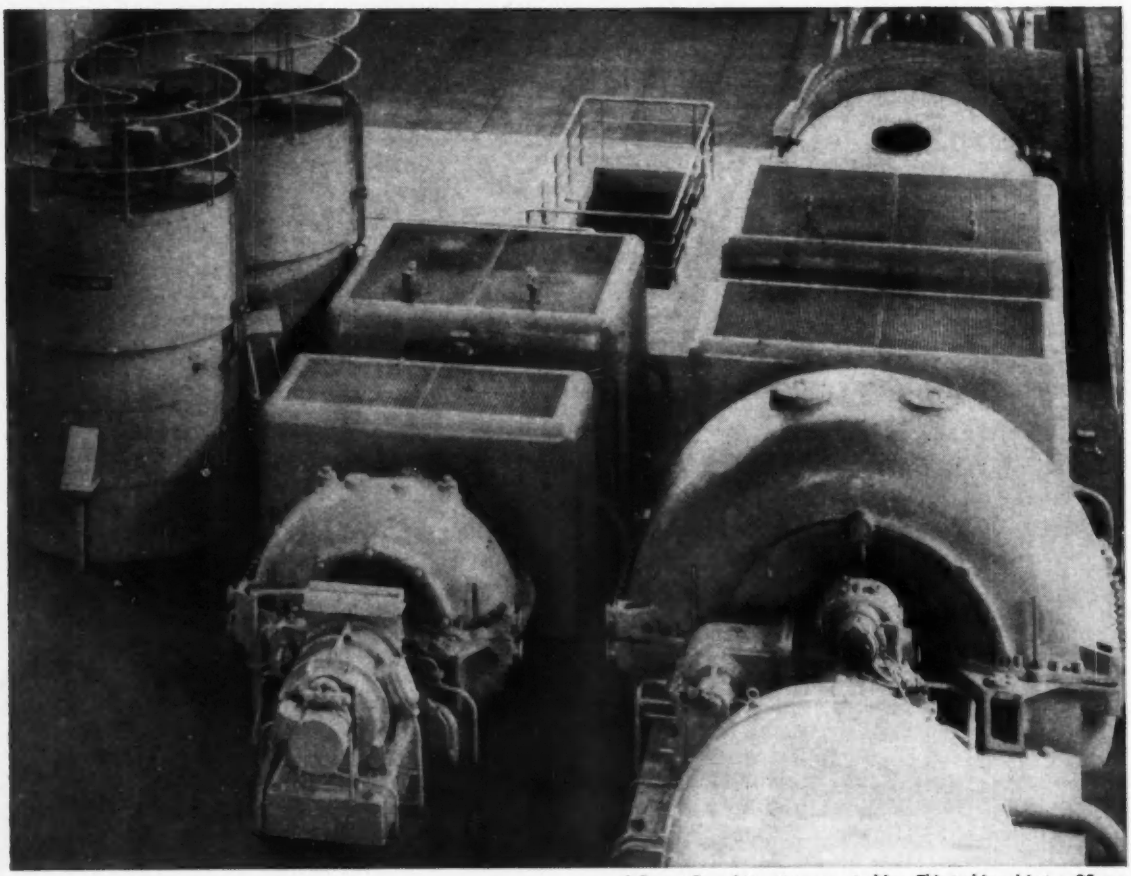
The first large gas turbine-generator, a 4,000 kw unit, was built by Brown Boveri and installed in 1939. It is still operating.

The world's largest gas turbine generating plant at Port Mann, Canada, is unattended! Its four 25mw Brown Boveri units are fully automatic and remote controlled.

Overhaul of two Brown Boveri gas turbine sets at the Pertigalete Cement Works, Venezuela, showed a typical condition: after 15,000 operating hours, components were almost like new. No sign of wear. No repairs or parts changes required.

Scores of Brown Boveri stationary gas turbines totalling over 1,300,000 kw installed capacity are driving generators, compressors and blowers in nearly continuous trouble-free operation—year after year. No other manufacturer can match this experience.

About Brown Boveri gas turbines: Sizes: 1,200 to 30,000 kw output. Single shaft sets for low initial cost. Double shaft, multi-stage units for lowest cost per kw and higher efficiency. Dual burners, quickly adaptable to gas or liquid fuels. Stationary, semi-mobile or mobile mounts. Completely automatic or remote controls.



A Brown Boveri two-stage gas turbine. This turbine drives a 25 mw generator part of which is visible at the lower right corner of the photo. Starting time from cold to full load is less than 20 minutes.

BROWN BOVERI Brown Boveri Corp., Dept. GT3, 19 Rector Street, New York 6, N. Y. Agents in 27 U. S. cities.

GT HOT LINE

JET-FIRED TURBINE TO RUN PIPELINE COMPRESSOR

There's a history-making compressor station now being built at Clementsville, Kentucky. Columbia Gulf Transmission is busy installing a unique combustor-turbine combination to help push gas through their 841-mile pipeline. Cooper-Bessemer, working with Pratt & Whitney, modified a P & W J-57 jet to supply hot gas to a turbine of their own design. Unit is expected to cut original costs by 50 percent . . . cut maintenance costs and parts inventory. Output is 10,500 hp; weight, 12 ton. That's a 95 percent weight reduction over turbines formerly used. Turbine can be replaced with a spare in only 4 hours. Fuel? Natural gas. And it's going to be all remotely controlled.

GE TURBOJET WINS WORLD'S ALTITUDE RECORD BACK FROM RUSKIES

A General Electric trophy went to Edwards Air Force Base test pilot Captain Joe B. Jordan who set a new world's altitude record of 103,395.5 ft on December 14th. His Lockheed F-104-C Starfighter was powered by the same GE J79 turbojet engine which powered Navy F4H Phantom II fighter to an unofficial world's altitude record on December 6th. Navy record topped a Russian record set last July.

ALSO, GENERAL ELECTRIC HAS TWO NEW ONES IN WORKS

There'll be a 75-hp turbine produced by General Electric on license from Bavarian Motor Works, Munich, West Germany if present negotiations materialize. Look for prototype at Gas Turbine Division Exhibit in Houston, March 6th to 9th. Also, GE is bringing out industrial versions of their successful J79. Model 240, adapted from the J79 jet engine, should find wide commercial applications because of its unusually efficient fuel consumption at full load (20,000 hp) of about 0.5 lb/hp hr and approximately 0.6 lb/hp hr at half load – all without use of heat exchanger.

AIRESEARCH RACKS UP IMPRESSIVE RECORD

Last month saw the 9000th gas turbine rolling off AiResearch's Phoenix production line. This young giant of the business began producing turbines back in 1947. Biggest producer of turbines in 30 to 1000 hp range, AiResearch jets are used as ground and airborne auxiliary power units, on missiles, helicopters as well as on small business aircraft.

AROUND THE WORLD IN 142 LABS

Lights are burning late in laboratories around the world. Experimenting and building of gas turbines ranging up to 1500 hp is currently taking place in some 142 labs, according to SAE past-president C. G. A. Rosen, just back from a European inspection tour.

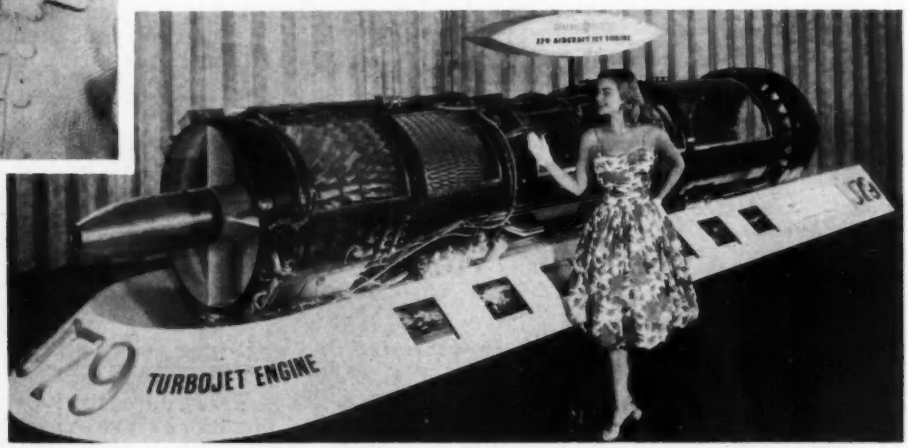
FORD'S LEVACAR AIMS AT 500 MPH

Ford research engineers are researching "Levapad" principle for vehicles – special slippers using high pressure air jets that raise vehicles only a fraction of an inch to eliminate friction. They say you'll be sliding over the rails at speeds up to 500 mph a few years from now. Propulsion will be provided by gas turbines. Don't confuse Levapad with current wingless craft raised by jet reaction or low-pressure air methods.

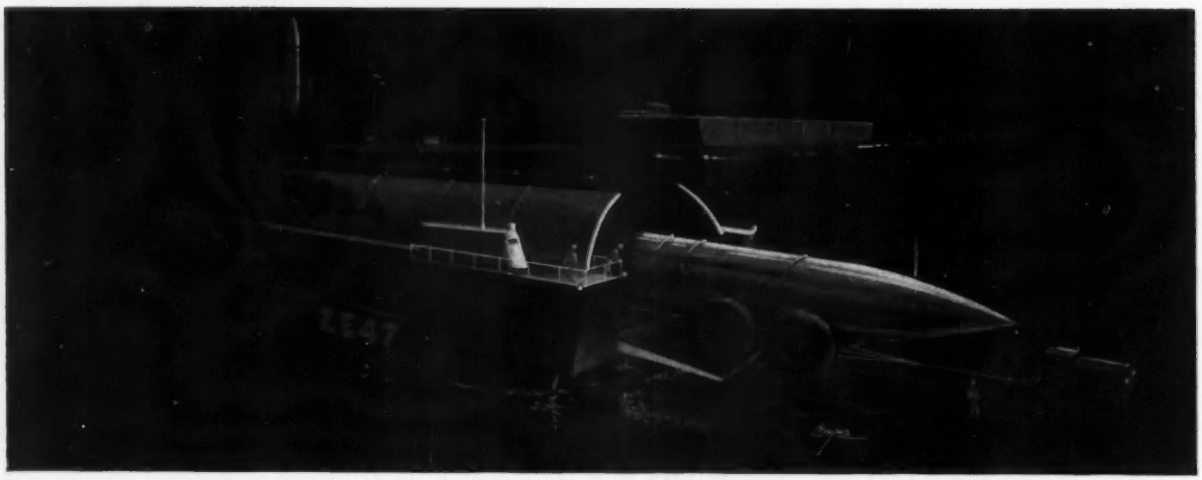
GT INDUSTRY NEWS

World's Smallest . . .

. . . one of World's Largest!



Tiny turbo-jet developed by Williams Research weighs just 23 lb. It's designed for rotor tip and light airplane applications. Compare it with GE's giant J79 that currently holds world's speed and altitude records.



Defense Department officials, constantly casting an eye around for ways to make our defense setup less vulnerable, are currently giving missile-launching railroad cars and missile-launching inland waterway barges a long, hard look. These mobile missile-launchers would make it difficult for potential enemies to pin point and wipe out our retalitory missile bases. Designed by E. H. Harlow of Frederic R. Harris, Inc., proposed barge—130 ft by 25 ft—would have a high-output gas turbine in each section of its catamaran hull.

Fluid Coupling Solves Fan-Drive Problem

Vertol Aircraft Corporation's Model 76 tilt-wing aircraft showed a real tail-fan driveshaft problem in preliminary tests. Severe torque fluctuations, as much as plus or minus 100% of steady torque, were found to exist in the shaft. Stiffening and inertia damping proved impractical.

Cyclic fluctuations were finally smoothed out and dynamic overshoot reduced to less than 5% by installing a Twin Disc fluid coupling in the drive line—a simple and effective solution.

Model 76, a STOL-type aircraft, is powered by a Lycoming T-53 gas turbine that has proven out well in this application. The aircraft was developed by Vertol for the Army Transportation Corps and the Office of Naval Research.

Garrett Looks to the Future

An article in Garrett Corporation's NEW FRONTIERS not only tells an interesting story of small gas turbines but looks into the future. They say that the future of these small turbines is not only in "whirligigs . . . and the smaller jets . . ." but industrially in: (1) air conditioning, heating and refrigeration; (2) earthmoving machinery; (3) marine use; and (4) in emergency power plants. They also feel that the ". . . turbine-powered automobiles on the highway . . . will come after the small turbines have firmly established themselves in other fields.

GE Flight-Tests Aft-Fan Jet in Caravelle

Mark VII Caravelle will be fitted with two General Electric CJ805-23 aft-fan power plants. The fan is a one-stage compressor-turbine wheel, free-floating and supported by two bearings. It rotates in the opposite direction to the main turbine shaft. Thrust of this jet will be around 15,000 lb giving ample power to the Caravelle, 2 jets producing a speed of approximately 540 mph. The plane should be in service in July of this year.

"Sectionalized" Overhaul Approved by FAA

The Federal Aviation Agency approved a new and far-reaching overhaul certification program for the General Electric CJ-805-3 commercial jet engine. FAA gave approval to TWA and Delta for a "sectionalized" overhaul program on Convair 880 powerplants, entering service in 1960.

"Sectionalized" overhaul concept, an advancement of wide-spread interest, will be put into practice for the first time with the G-E CJ-805. Initial time between overhauls will be 1600 hours for the cold section, 900 hours for the hot section. "Cold section" is defined as all parts of the basic engine forward of the rear compressor frame or engine fire wall, including accessories; "hot section" is defined as all areas of the basic engine aft of the fire wall.

R. B. Smith, manager of GE's CJ-805 service group, said "We estimate that overhaul material and labor costs per engine hour will be approximately 20% less for engines overhauled at the 1600/900-hr rate than for engines overhauled at the conventional 1000-hr rate for all engine sections." Smith emphasized that this recognizes the inherent temperature differences that exist in all turbine engines and the resulting differences in wear and deterioration rates that occur. FAA's approval permits TWA and Delta to establish overhaul periods more nearly suited to the mechanical design of turbojet engines.

Boeing Seeks Certification for New Aircraft Engine

Boeing has filed for FAA certification of a gas turbine of 400 or more horsepower to be used in executive-type fixed-wing aircraft and light helicopters. The new engine is expected to be in quantity production early in 1961 after certification test, scheduled to start late in the year. The new Boeing power plant was designed and built by the Industrial Products Division under a Navy contract to produce a suitable turbine engine for helicopter trainers.

GT "COMING UP" REMINDER

MARCH 10-11 Institute of the Aeronautical Sciences, Flight Propulsion Meeting (Classified), Cleveland, Ohio.

MARCH 15-17 Society of Automotive Engineers, National Automobile Meeting, Sheraton-Cadillac Hotel, Detroit, Michigan.

MARCH 22-24 Society of Automotive Engineers, National Production Meeting, Statler Hotel, Cleveland, Ohio.

APRIL 3-8 American Institute of Electrical Engineers, EJC Nuclear Congress, New York City.

APRIL 4-8 The American Society of Mechancial Engineers, Nuclear Congress and Exhibit, Coliseum, New York City.

APRIL 5-8 Society of Automotive Engineers, National Aeronautic Meeting (including production forum and engineering display), Hotel Commodore, New York City.

APRIL 19-21 American Society of Lubrication Engineers, Annual Meetings and Exhibits, Netherland-Hilton Hotel, Cincinnati, Ohio.

APRIL 20-22 Institute of the Aeronautical Sciences, Manned Space Stations Symposium (IAS, MASA, and The Rand Corp.). Ambassador Hotel, Los Angeles, California.

APRIL 25-29 American Welding Society, Annual Meeting and Welding Exposition, Hotel Biltmore, Los Angeles, California.

APRIL 25-29 The American Society of Mechanical Engineers, Metals Engineering Division — AWS Conference, Biltmore Hotel, Los Angeles, California.

MAY 17-19 The American Society of Mechanical Engineers, Production Engineering Conference, Hotel Schroeder, Milwaukee, Wisconsin.

MAY 22-26 The American Society of Mechanical Engineers, Oil and Gas Power Conference and Exhibit, Muehlebach Hotel, Kansas City, Mo.

MAY 23-25 Institute of the Aeronautical Sciences, Telemetering Conference (IAS, AIEE, ARS, ISA) Hotel Miramar, Santa Monica, Calif.

MAY 23-26 The American Society of Mechanical Engineers, Design Engineering Conference and Show, Statler-Hilton Hotel, New York City.

MAY 26-27 Institute of the Aeronautical Sciences, Specialists Meeting on Guidance of Aero/Space Vehicles, Boston, Mass.

GT CONTRACTS PROCUREMENTS

Some gas turbine procurements initiated and contracts awarded during recent months by various agencies of the U. S. Government are listed. This material is from the U. S. Department of Commerce publication "Synopsis of U. S. Government Proposed Procurement, Sales and Contract Awards." Companies are encouraged to submit similar data covering their activities to the Editor for inclusion here.

1. San Antonio Air Material Area, USAF, Kelly A. F. Base, Texas. "Repair kit and spare parts, 75 to 1000 each applicable to J-57 and J-75 engines in support of various aircraft. (PR:SA-9-02HI-9919)"—$281,361—Holley Carburetor Co., Warren, Michigan.

2. U. S. Department of the Navy, Bureau of Ships, Washington 25, D. C. "Gas turbine-driven portable fire pumps. Contracts NObs-78089. (IFB-600-8144-59-S) Spec No. MIL-P-21745 (Ships) Qty, 80 each"—$551,136—Solar Aircraft Co., San Diego, Calif.

3. AMC Aeronautical Systems Center, U. S. Air Force Center, Wright-Patterson A. F. Base, Ohio. "Facilities for the J-85 Engine (PR BI-9-F-9185)"—$701,350—General Electric Co., West Lynn, Mass.

4. AMC Aeronautical Systems Center, U. S. Air Force Center, Wright-Patterson A. F. Base, Ohio. "28 J-79-GE-5A Turbojet Aircraft Engines with afterburner for use with the B58 aircraft (PR EP-9-2840-4890)"—$3,000,000—General Electric Co., Cincinnati, Ohio.

5. AMC Aeronautical Systems Center, U. S. Air Force Center, Wright-Patterson A. F. Base, Ohio. "Development of the T55-L-5 engine through qualification. (FOR: HC-1 B Helicopter—Army) (PR's 57169) (MIPR R56-675-Tc Amend. 4) 62427 (MIPR R59-18-TC-RE Amend. 3)"—$1,696,800—Avco Corp., Lycoming Div., Stratford, Conn.

6. Department of the Navy, Bureau of Aeronautics. "Services and materials to conduct a product improvement program on the Model J34 turbojet engine, NOas 59-0287-c(PP-21-166-59)"—$4,800,000—Westinghouse Electric Corporation, Washington, D. C.

7. Hq. Oklahoma City Air Material Area, USAF, Tinker A. F. Base, Oklahoma. "Overhaul and/or repair 275 each J35-A-35 Aircraft Engines (RFP OC-O-O2A-0046)"—Job—$767,196—Southwest Airmotive Co., Love Field, Dallas, Texas.

8. AMC Aeronautical Systems Center, U. S. Air Force Center, Wright-Patterson A. F. Base, Ohio. "Modification and overhaul of 31 each Power Units, AiResearch Model GTU85-2, Gas Turbine Engine, Aerno: 42-2353; Spare Parts and Data. For C-133 Aircraft. (PR's EA-9-OL B-4809; WR-9-2835-5967)"—$204,539—The Garrett Corporation, AiResearch Manufacturing Div., Phoenix, Ariz.

9. AMC Aeronautical Systems Center, U. S. Air Force Center, Wright-Patterson A. F. Base, Ohio. "Facilities for overhaul of the J-73 Engine. (PR BI-9-F-9035)"—$240,000—Curtiss-Wright Corp., Utica Division, Utica, Michigan.

10. AMC Aeronautical Systems Center, U. S. Air Force Center, Wright-Patterson A. F. Base, Ohio. "T53-L-5 Shaft-Turbine Aircraft Engines (For use in HU—1B Flight Test Program) (PR 47916) (MIPR R59-14-TC-RE)"—$524,968—Avco Corp., Lycoming Div., Stratford, Conn.

11. Hq. San Antonio Air Material Area, USAF, Kelly A. F. Base, Texas. "Spare Parts and Kits applicable to 4-349-626089 Fuel Control in support of J69T9 engine for T37 aircraft, 20 to 2351 each and supporting data. (PR: SA-9-03D-7670, -1, -2, -3, -4, -5)"—$386,295—Bendix Aviation Corp., Hamilton Div., Hamilton, Ohio.

12. San Antonio Air Material Area, USAF, Kelly A. F. Base, Texas. "Spare parts, 7 to 599 each and supporting data. Items applicable to J57-P-55 engines in support of F101 engines. (RFP PR: SA-9-03D-9869 and -1)"—$25,022—Holley Carburetor Co., Warren, Mich.

13. San Antonio Air Material Area, USAF, Kelly A. F. Base, Texas. "Spare parts, 7 to 599 each applicable to Holley Bleed Controls used on J57P55 engines in support of F101 series aircraft plus first year's spare parts support. (RFP PR: SA-9-02H109916)"—$75,654—Holley Carburetor Co., Warren, Mich.

14. San Antonio Air Material Area, USAF, Kelly A. F. Base, Texas. "Spare parts, 16 to 576 each applicable to modification of Holley Fuel Controls A11404 and T11422 to A11431 series used on T34 engines in support of C133 aircraft. (RFP PR: SA-9-03D-9908 & -1)"—$62,145—Holley Carburetor Co., Warren, Mich.

(Continued on page 49)

INDUSTRY NEWS . . .

Allison Prop-Jet Approved for Super Convair

First Super Convair powered by the Allison T56 will take to the air with full certification scheduled for March. The T56 now in the Super Convair has the 1000-hr overhaul time approved for identical engines in the Lockheed Electras. Included among the variety of tests were single-engine take-offs, climbs and landings, engine calibration tests, determination of stall and minimum control speeds, and speed checks to demonstrate guaranteed standard-day speed of 342 mph at 20,000 feet at 48,000 pounds.

Approval to fly the Model 501-D13 conversion engines to 1000 hours before overhaul came from the FAA since the YC-131C—a proto-type military version of the Super Convair commercial airliner—completed the flying portion of the FAA evaluation program.

Eleven conversions already are on order by corporate operators. Three commercial airlines presently are negotiating for the prop-jet conversion package which includes nacelle modifications necessary for installation of the lighter and more powerful Allison prop-jet engines.

Navy Buys More J-57's

The Navy has awarded a $27.3-million contract to Pratt & Whitney Division of United Aircraft Corporation, East Hartford, Connecticut, for additional production of advanced J-57 engines. Engines procured under this contract will power the Navy's F8U-2N Crusader aircraft. The F8U-2N is a carrier-based, limited all-weather jet fighter. Basically a development of the F8U-2, it features increased capability for detecting and destroying targets in darkness and in inclement weather.

Kaman Goes 100% Gas Turbine

All equipment built by Kaman Aircraft Corporation at Bloomfield, Conn. is now to be powered by gas turbines. In 1951 Kaman was the first to fly a shaft-turbine (Boeing) helicopter. It will only be a question of time when other companies can announce "100% Gas Turbine-Powered."

(Continued on page 48)

GT PEOPLE PLANTS PLACES

H. F. Chesebrough

Chesebrough Chosen SAE Chief for 1960

Harry E. Chesebrough, vice president of Chrysler Corporation, has been elected president of SAE for 1960. He took over the reins at SAE's Annual Meeting in Detroit.

Mr. Chesebrough has served SAE in many capacities during his 18 years of membership. He recently played an important part in the reorganization of the Society that equipped SAE to meet the fast step-up in rate of technical progress.

He is a familiar figure and a respected engineer in the automotive world. During the last 25 years he has held jobs at Chrysler ranging from chief engineer, DeSoto Division . . . to chief body engineer . . . to general manager, Plymouth Division, a position he presently holds.

AiResearch Industrial Division

Charles W. Clarke has been appointed Manager of Manufacturing for Garrett Corporation's AiResearch Industrial Division, Los Angeles. He succeeds Lloyd Olmsted, who relinquished the position for reasons of ill health. In naming Clarke, AiResearch Industrial Division Manager Wilton Parker also announced the advancement of William M. Warner to the newly created position of Material Manager.

Clarke came to the Garrett organization in 1942, starting with the AiResearch Manufacturing Division of Los Angeles. Later, he went to the AiResearch Manufacturing Division of Phoenix, returned in a couple of years to L. A. as chief production engineer. He advanced to the post of Assistant Director of Manufacturing (1959), from where he transferred to his present assignment. Warner started at Phoenix in 1956, moved to AiResearch Industrial two years later as Manager of Purchasing.

New Sales Setup For Boeing Turbine Division

Boeing Industrial Products Division, builders of the Boeing small gas turbine and high-precision aircraft products, has combined all sales functions in a broadened marketing organization. William Van Amerongen has been named acting-director of marketing. He will report directly to Frank Korsberg, division general manager, who said the reorganization combines market research, applications engineering, sales, service and spares to coordinate marketing efforts of Boeing gas turbines and other division products.

B. C. Karther

W. Van Amerongen

W. St. Germain

D. C. Cook

Other changes in the company's sales organization include the appointment of William St. Germain as manager of military turbine sales; B. C. Karther, manager of commercial turbine sales; Douglas C. Cook, manager of European turbine sales; Daniel F. McGrath, service manager and Ralph Parr, spares manager; all will report to Van Amerongen.

D. M. Salls

C-B Names Manager for Gas Turbine Sales

David M. Salls, manager for Gas Industry Marketing for the Cooper-Bessemer Corporation, has been named product sales manager for the company's RT-248 gas turbine. This gas turbine, driven by a modified J-57 jet engine, was developed by Cooper-Bessemer Corporation in cooperation with Pratt & Whitney Aircraft Division, United Aircraft Company.

The new unit is scheduled for its first pipeline installation at the Columbia-Gulf Clementsville, Kentucky, compressor station next summer. Mr. Salls first joined Cooper-Bessemer in 1941. In 1947 he became associated with Texas Eastern Transmission Corporation and returned to Cooper-Bessemer in 1951. Throughout his work at C-B, his efforts have been concentrated on all phases of gas industry power and compression needs.

Sub-Contractors Conference At Garrett Corporation

350 representatives from 200 firms in 10 states assembled in Phoenix, Arizona, January 26th to attend a reliability conference held by AiResearch Manufacturing Company. These suppliers are doing a $3-million monthly business volume with the Phoenix division of The Garrett Corporation. Dr. Helmut R. Schelp, AiResearch chief engineer, discussed the growing market and increasing precision required to produce the small gas turbine (jet) engines and other units manufactured by AiResearch. The Phoenix firm is the world's largest producer of turbines in the 30 to 1000 hp class.

AN ECONOMIC SOLUTION TO PEAKING PROBLEMS

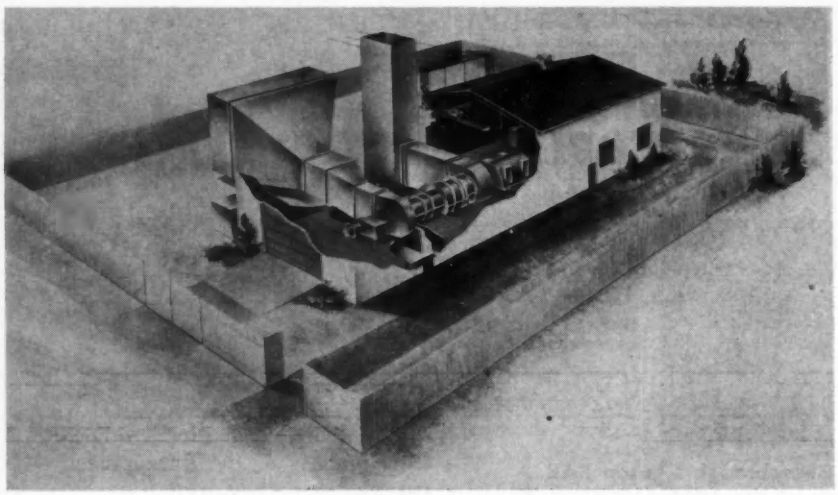


Fig. 1. Typical gas turbine peaking plant with rated capacity in the 20,000 to 25,000-kw range features minimum space requirements, little or no cooling water and low noise level.

Sharply rising electrical demand curves, higher peak loads, plus distribution problems arising from decentralization trends are all problems that utilities can solve with gas turbine peaking plants—practically and economically.

GAS TURBINES are finding growing acceptance as prime movers in the electric utility field. Growth in this application has been substantial. World-wide status in 1952 totaled 44 turbines with a capacity of about 430,000 hp. Five years later there were 125 units representing some 1,546,000 hp (1). A number of General Electric Company gas turbines for electric power generation are shown in Table I. Capacities range from 5000 to 21,500 kw. Westinghouse Electric Corporation gas turbine power generating sets now total 23 with a combined capacity of 142,350 kw. These turbine-generators vary in size from 1250 to 27,500 kw, Table 2.

Peak loads, a high power demand for a short period of time, are being supplied in many utility systems by gas turbines. Four peak load plants are shown in Table 1 and three in Table 2, with ratings from 1250 to 27,500 kw. There are many advantages that make this prime mover attractive for peak load use.

What's a peaking plant like?

A typical gas turbine peaking plant, 20,000-25,000 kw, is shown in Fig. 1. This is an artist's sketch made from detailed design drawings. The building is of steel frame construction, approximately 30 ft by 100 ft. Siding and roof are of standard asbestos—steel panels insulated with glass fiber blocks. An overhead crane is included for ease of construction and maintenance.

The turbine drives a conventional air-cooled generator and exciter. Equipment for complete automatic control of turbine, generator, and auxiliaries is located at the far end of the building. This is an unattended station and includes supervisory and tele-metering equipments, both at the station and for the remote control point.

TABLE I
GENERAL ELECTRIC GAS TURBINES
FOR
ELECTRIC POWER GENERATION

Units	Rating, kw	User
1a	21,500	Electricidad de Caracas, Venezuela
1a	20,500	Philadelphia Electric Co., Pa.
1a	20,500	Central Vermont Pub. Service Corp.
2	19,750	British Columbia Power Commission
2	18,000	British Columbia Power Commission
2a	16,500	Orlando Utilities Comm. Florida
1	16,000	Creole Petroleum Corp., Venezuela
2	16,000	Planta Electrica of Gropo Ind., Mexico
2	8,700	Creole Petroleum Corp., Venezuela
2	7,500	Industria Col. de Fertilizante, Columbia
1b	5,000	Crisp County Power Comm., Georgia
2	5,000	Empresa Col. dePetroleos, Columbia
1	5,000	Gates Rubber Company, Denver, Colorado

a. Peak load plant
b. Gas turbine—steam plant combination

TABLE 2
WESTINGHOUSE ELECTRIC CORPORATION GAS TURBINES FOR ELECTRIC POWER GENERATION

Units	Rating, kw	User
1a	22,000-27,000	Philadelphia Electric Co., Pa.
1	8,100	Altos Hornos de Mexico
1a	5,000	Electricity Board of Beirut, Lebanon
2	5,000	West Texas Utilities
5	5,000	Mene Grande Oil Company
1	5,000	U. S. Army, Corps. of Engrs., Railway Unit
1	5,000	Asiatic Petroleum Corp., Borneo
2	5,000	Asiatic Petroleum Corp., Venezuela
4	5,000	Dase De Sao Paulo, Brazil
3	5,000	Petroleos Mexicanos, Veracruz, Mexico
1	5,500	Cia Nacional de Electricidad, Mexico
1	5,500	City of Austin, Minn.
1a	1,250	City of Larned, Kansas
1	5,000	Manufacturas Metalicas Madrilenas, Spain

a. Peak load plant

The large structure at the gas turbine air intake is an evaporative cooler, designed to increase the turbine capability at ambient temperatures above 60° or 70°F. Intake ducting incorporates a silencer. For particularly sensitive locations, provisions have been made for adding exhaust silencers at the base of the stack.

A closed radiator-type of cooler is provided for generator air and lube oil cooling. Only a negligible amount of water is required for make-up. Provisions are also made for underground fuel storage tanks, main power transformer, switching structure and oil circuit breaker for delivering the plant output into a 34.5-kv line. A cross section of a 20,500-kw plant is shown in Fig. 2.

What are the advantages?

The following advantages make the gas turbine a most attractive source of power for peak demands:

a. Reliability.

b. Flexibility. Plants require little or no cooling water and can burn natural gas or non-premium distillate fuel.

c. Low forced outage time which results in a high reliability factor.

d. Low maintenance cost.

e. Quick starting.

f. Ability to handle fluctuating loads.

g. Reduced number of operating personnel.

h. Low initial plant investment.

i. Compact units which result in lower installation costs.

j. Simplicity of operation, requiring less training of personnel.

k. Moderate unit size. A 20,000 to 30,000 kw plant is small enough to fit close to the load and save cost of bulk transmission. Size is such that peaking demands on a large system can be fulfilled with a manageable number of units.

How about economics?

An analysis of gas turbine peak load prime movers has been made with the following system conditions:

a. Capitalization rate for both steam and gas turbine stations is 15%.

b. System has a winter peak.

c. Future steam turbines will be rated 150,000 kw and cost $150/kw to install.

d. Gas turbine is remotely operated, distillate oil-fired, with plentiful cooling water supply, and installs for $109/kw.

e. Steam plant coal cost is $0.30/million Btu.

f. Gas turbine plant distillate oil cost is $0.70/million Btu.

g. Over-all system heat rate is 11,000 Btu/kw-hr.

h. Net station heat rate of 150-MW plant is 9600 Btu/kw-hr.

i. Net station heat rate of gas turbine plant is 15,650 Btu/kw-hr.

The cost analysis showed the following savings:

a. Deferred investment	$14.30/kw
b. Interest during construction	$ 2.44/kw
c. Operating labor	$10.80/kw
d. Starting and spinning reserve	$ 0.52/kw
e. Transmission effect	$40.00/kw
	$68.06/kw

A fuel penalty, due to an increase of overall fuel rate, is $42.00/kw. The resulting saving is $28.06/kw. 109.00 − 28.06 = $82.94/kw.

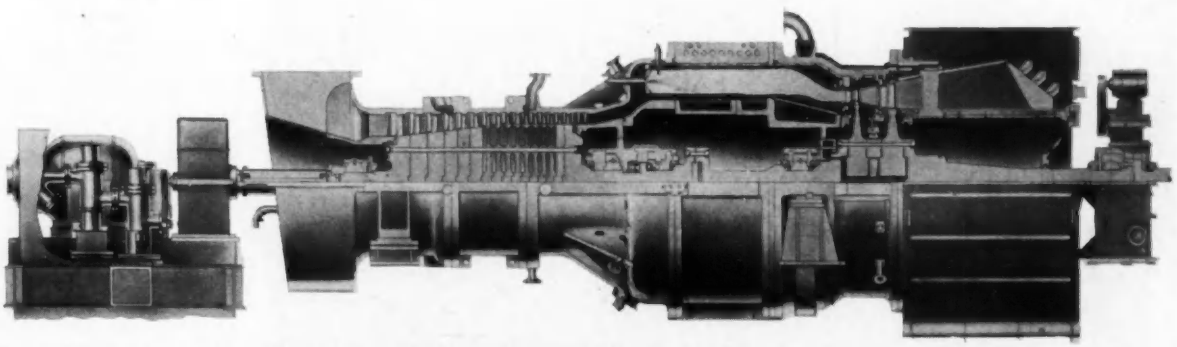


Fig. 2. Cross section of General Electric's new 20,500-kw peaking combustion gas turbine.

What can you expect in availability? . . . reliability?

Experience with gas turbines in industrial service has been excellent under many operating conditions. General Electric industrial turbines have accumulated about 4,000,000 hours of operating time. Numerous turbines are now in service with over 40,000 hours operation while some machines have run continuously for more than 13,000 hours.

One group of large turbines in 1957 had a forced outage rate of less than 0.5%. This is a reliability factor greater than 99.5%. Combined maintenance and forced outage time was 2% or an availability of 98%.

About lube oil and cooling water . . .

A 20,500-kw plant requirements for cooling water are estimated at 30 gpm. Lubricating oil consumption for this turbine is only a few gallons each year.

Maintenance experience . . .

Practices vary with the type of fuel burned and also with service conditions. Partial inspections may be required every 8000 hours for machines burning natural gas and operating with high use factors. Complete inspections of such units may be performed every 24,000 hours, 3-year intervals. Some units get their inspections at 16,000-hr periods. Intermittent service turbines, 50-60% use factors, and frequent starts, generally get a partial inspection every 4000-5000 fired hours with a full inspection each 8000-10,000 fired hours.

Time required for minor inspections is 350-450 man-hours. Major inspections may vary from 800 to 900 man-hours. It is expected that time for major inspections will be reduced to 0.1 man-hr/hp and 0.04 man-hr/hp for minor inspections.

And component life expectancy . . .

Number of operating hours possible on various parts will depend on fuel burned and the type of service. Hour-life of major components of gas and oil-fired units is shown in Table 3. Gas-fired units in continuous service have component life in excess of 30,000 fired hours. These include: combustion liners, fuel nozzles, first-stage turbine nozzles, second-stage turbine nozzles, turbine buckets and turbine wheels.

Looking ahead . . .

The gas turbine has demonstrated a most outstanding performance in electric power generation service. With a record of reliability, quick startup ability, ease of maintenance and low effective installed cost, this prime mover should find a rapid increase in peaking as well as base-load power applications.

TABLE 3
HOURS LIFE OF GENERAL ELECTRIC GAS TURBINE COMPONENTS (2)

Component	Gas-Fired Continuous Service	Residual-Oil Intermittent Service
Combustion liners	Over 30,000 hours	3000 to 5000 hours
Fuel nozzles	Over 30,000 hours	Over 10,000 hours
First-stage turbine nozzle	Over 30,000 hours (minor repairs)	5000 to 10,000 hours depending on service conditions
Second-stage turbine nozzle	Over 30,000 hours	Over 20,000 hours (minor repairs)
Turbine buckets	Over 30,000 hours	Over 20,000 hours
Turbine wheels	Over 30,000 hours (minor repairs)	Over 20,000 hours (minor repairs)

REFERENCES

1 "Gas Turbine Progress Report—1958—Industrial and Central Station"—B. G. A. Skrotzski, Paper No. 58-A-46L, presented at the Annual Meeting of the American Society of Mechanical Engineers, New York City, December 1958

2 "Operating Experience of General Electric Gas Turbines"—H. D. McLean, Paper No. 58-GTP-18, presented at the Gas Turbine Power Conference and Exhibit, American Society of Mechanical Engineers, Washington, D. C., March 2-6, 1958.

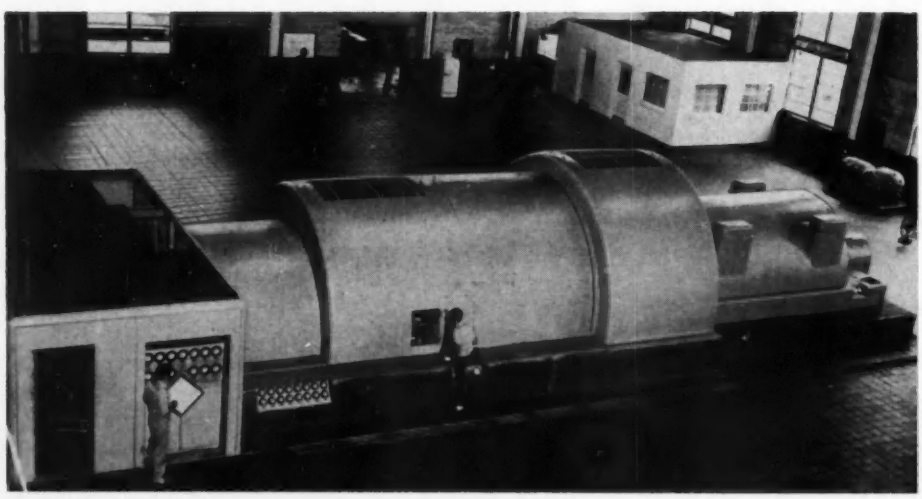


Fig. 3. Here is the complete prime mover—no boiler rooms, external systems or accessories. It's a 16,500-kw GE combustion gas turbine-generator set.

Auxiliary Gas Turbines becoming a prime power source for industry

Helmut Schelp, chief engineer, AiResearch Manufacturing Division of Arizona, Phoenix, surrounded by typical gas turbines now in production ranging in size from 30 to 850 hp. Clockwise from the top: GTC 85-28 GTCP 105 • GTP 70-6 • GTP 30-1 • GTP 70-10 • GTU 85-2.

AiResearch Gas Turbine Engines, the most widely used power source for the starting, air conditioning, cooling and heating of jet aircraft, now are becoming a prime power source for industry.

Easier to maintain because of few moving parts, these lightweight gas turbine engines develop more horsepower per pound of weight and size than any other engine. Achieving their greatest efficiency at maximum speeds, they run on almost any fuel and start immediately in any weather.

Present prime power applications of AiResearch gas turbines for industry: earthmoving equipment; small independent generator plants; marine use; helicopters and small conventional aircraft; emergency power plants; air conditioning, heating and refrigeration; atomic energy (closed cycle gas turbine with atomic energy heat source).

First to design and develop a successful small gas turbine engine, Garrett is the world's largest manufacturer of lightweight turbomachinery — having delivered more than 200,000 units, including 9000 gas turbines of all types ranging from 30 to 850 hp. Through its AiResearch Manufacturing Divisions, The Garrett Corporation is now offering this experience to all industry.

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

LOS ANGELES 45, CALIFORNIA • PHOENIX, ARIZONA

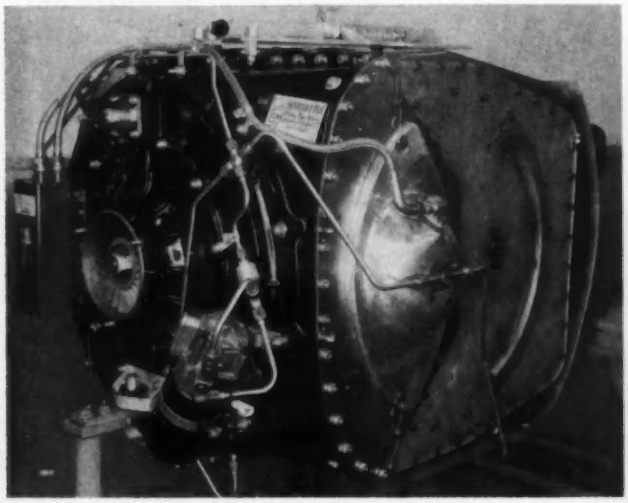
OTHER DIVISIONS AND SUBSIDIARIES: AIRESEARCH INDUSTRIAL • AIRESEARCH AVIATION SERVICE • GARRETT SUPPLY • AIR CRUISERS AIRSUPPLY-AERO ENGINEERING • GARRETT MANUFACTURING LIMITED • C. W. MARWEDEL • GARRETT INTERNATIONAL

Allison's GMT-305

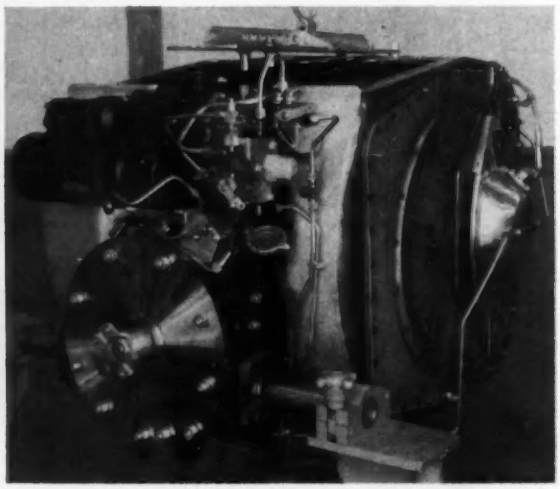
"Whirlfire"

Concept of a single basic application — vehicular propulsion — freed GM designers from restrictions other applications might impose. They have produced a rugged, efficient regenerative gas turbine, ready to compete with reciprocating engines on their own terms.

by J. C. Fetters, Chief Engineer—Turbine Engines
Allison Division, General Motors Corp.



You're looking at the front and left side of Allison's "Whirlfire." This is the baby that's going to give the piston engines a run for their money economy-wise.



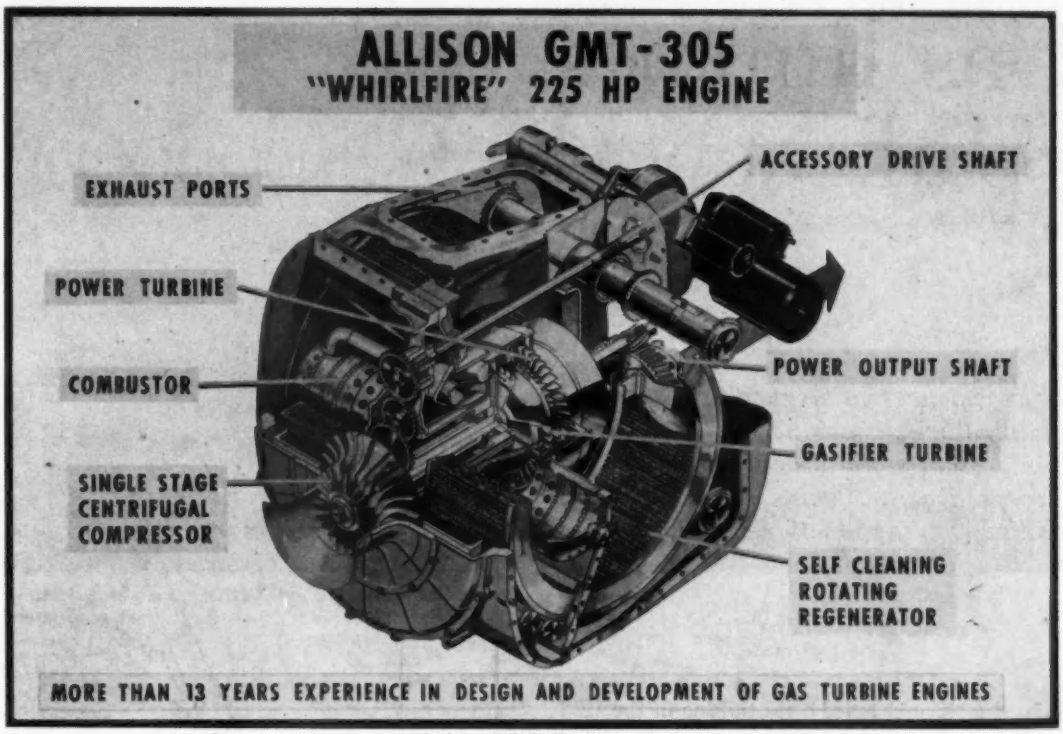
Here you're seeing the GMT 305 from the rear and rightside. Drive is on the left.

ALLISON is developing a rugged workhorse-type gas turbine for vehicular applications which previously have been powered exclusively by spark and compression-ignition engines. Today, this gas turbine, the Allison Model GMT-305, can compete in economy with reciprocating engines due to a major engineering breakthrough—practical application of the regenerative cycle to a small gas turbine.

The GT-305 "Whirlfire" 225-hp engine, developed by GM Research Laboratories, is basically a vehicular propulsion-type engine. Since it is not hampered by weight restrictions normally associated with aircraft, GT-305 design results in ruggedness and long life and the engine's constructional simplicity ensures ease of maintenance. Also, practical application of the regenerative cycle has resulted in economical operation.

Design Features . . .

Design of the GMT-305 engine effectively integrates the components into a clean compact unit. Two turbines are arranged on a common horizontal axis. Designed for an inlet temperature of 1650°F, the first-stage turbine turns the radial-flow compressor at 33,000 rpm through the connecting shaft. The second stage or power turbine, immediately behind the first but mechanically separate, drives the output shaft through a single-stage helical reduction gear. The power turbine develops full power at 24,000 rpm, reduced to 3500 rpm at the output flange. A speed-limiting governor permits the output shaft to turn as high as 4500 rpm to take advantage of the flat characteristic of the gas turbine horsepower curve.



Cutaway gives you a good idea of "Whirlfire's" compact package. Regenerators for this small turbine mark a major engineering breakthrough for GM.

The two drum-shaped regenerators are located on either side of the turbine shaft, just behind the compressor casing. A bulkhead extending from top to bottom of the casing combines with side covers to form a high-pressure plenum. Each regenerator passes through the bulkhead so that about one-third of its circumference is in the high-pressure plenum and the remaining two-thirds in the exhaust plenum. Combustors are located in the high-pressure plenum between the regenerators and bulkhead. The turbines are located within the passage between the high and low-pressure plenums.

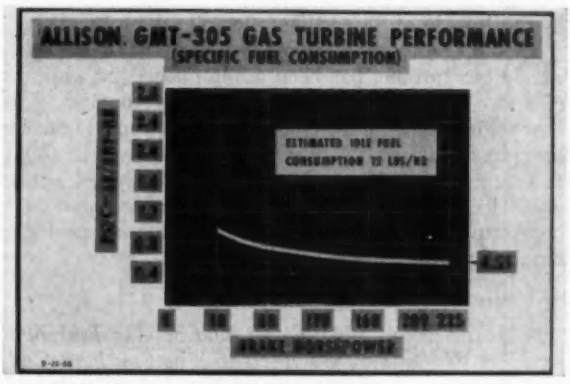
Compressed air discharged from the compressor into the high-pressure plenum chamber is heated as it passes radially inward through the front segments of the porous generator drums. Heated air then goes through the combustors where fuel is burned to bring the temperature up to 1650°F at design speed. The hot gas then expands through the turbines and is discharged within the exhaust plenum. Exhaust gas is cooled as it passes radially through the rear segments of the regenerator drums. The rotating regenerator drums transfer heat recovered from the exhaust gas to the compressed air passing through the drums in the high-pressure plenum.

Power for the rear-mounted accessories is supplied through a shaft, near the top of the engine, paralleling the main turbine shaft. Helical reduction gears, just behind the compressor, drive the accessory shaft from the gasifier turbine shaft. The gear-type engine lube oil pump is located just behind the top gear of the accessory drive train. Accessories are mounted at right angles to the drive shaft across the rear of the engine for maximum compactness.

Immediately ahead of the accessory case is a right-angle worm reduction gear driving the upper of two regenerator support shafts. Rollers on both the upper and lower shafts engage the rims of each regenerator drum, locating them so they can rotate about their axes. Pinions on the upper shaft engage the geared regenerator rims to drive them at about 30 rpm at rated engine speed.

The drum-type regenerators of the GMT-305 engine are characteristic of the integrated engine design concept. Engine parts are arranged compactly with a straight-through air flow path and complete elimination of inter-connecting ducts. This results in minimum

(*Continued on page 35*)


ALLISON GMT-305 GAS TURBINE PERFORMANCE
(SPECIFIC FUEL CONSUMPTION)
ESTIMATED IDLE FUEL CONSUMPTION 72 LBS/HR
BRAKE HORSEPOWER

Heat exchangers are responsible for the low fuel consumption shown on this performance chart.

Gas Turbines Spark New Marine Concepts

Naval experience* in pioneering installations brings marine gas turbines to their present state of development and acceptance . . . points to broad naval and commercial applications.

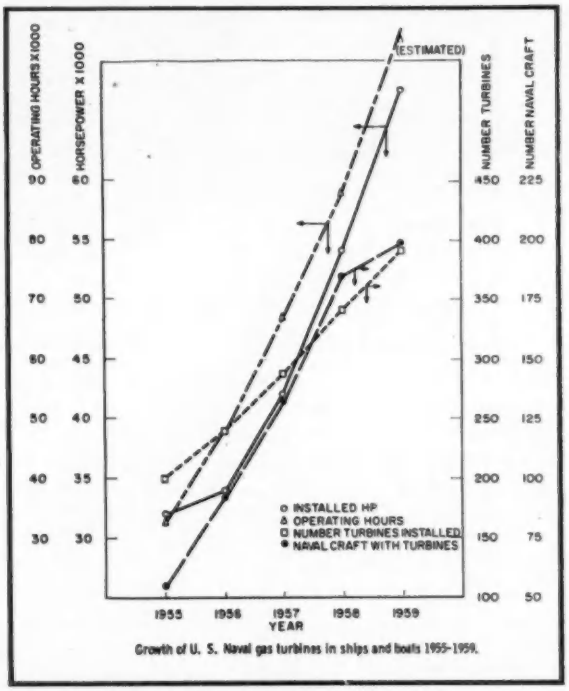
IN 1951, the Navy installed a gas turbine in the USS TIMMERMAN. It was a 250-kw unit built by the Solar Aircraft Company and used for emergency generator service. Since that time, gas turbines have steadily gained acceptance in both naval and merchant marine service.

Following this first major step the US Navy began installation, in 1952, of 184 Boeing 502-6 160-hp gas turbines in the MSB-5 Class mine-sweepers. Growth in US Navy use of marine turbines during the period 1955-1959 is shown in the accompanying chart.

Gas turbines installed and to be delivered in 1959 involve some 199 craft, 397 turbines with a total installed horsepower of 64,498. These have accumulated some 88,975 hours operating time, Table 1. Applications include engines as small as 46 hp and as large as 4000 hp. Total power installed on any single craft varies from 46 hp to 8000 hp.

Some 26 turbines are currently under procurement for installation in 23 naval craft and shore stations. They represent a total of over 9200 hp. A number of new gas turbines are now under development, sponsored by the Bureau of Ships. These include the following:

a. Westinghouse development of a 7500-hp light-weight gas turbine, has been accomplished by addition of a free power turbine to an aircraft jet engine. This new engine has a total weight of 8075 pounds. It can be brought from a cold condition to rated power in about 120 seconds. Specific fuel consumption at rated power is 0.8 lb per hp-hr. This engine is ideally suited as a booster power plant in ships where additional power is required for high speed.



Growth of U. S. Naval gas turbines in ships and boats 1955-1959.

Just a glance at the above chart quickly shows how rapidly gas turbine use has moved lately in the U.S. Navy.

b. A 3500-hp turbine is being developed by the Utica Division of the Curtiss-Wright Corporation. It is suitable for base-load propulsion and could also be applied for peak-load plants in combination with gas turbine, diesel or steam. This turbine has a specific fuel consumption, at rated power, of 0.59.

c. A light-weight 1100-hp engine is being developed by Solar Aircraft, in both constant and variable-speed versions. This unit has demonstrated a specific fuel consumption of 0.615 at rated power. The dry weight is 725 pounds. Starting time for the constant-speed version driving a generator is 10 seconds.

d. The Boeing Airplane Company has under development a small light-weight 350-hp gas turbine suitable for small boat propulsion and auxiliary drive. It has shown a specific fuel consumption of 0.8.

Progress is not without pain . . . .

The impressive number of operating hours accumulated on early engines was not realized without some

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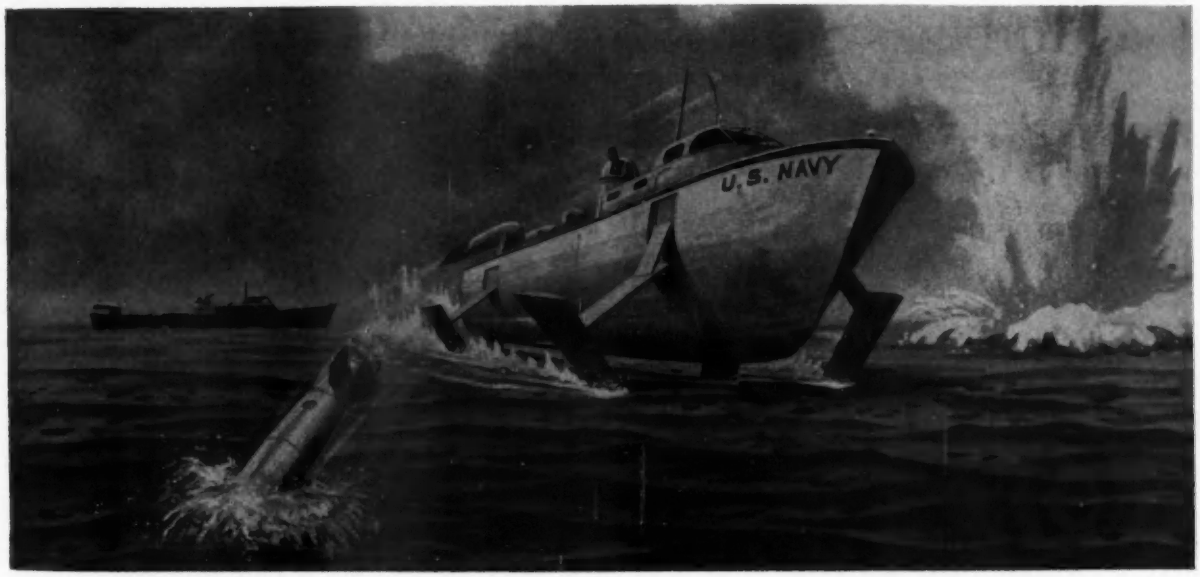
* *From the paper "U.S. Navy's Marine Gas Turbines" by John W. Sawyer, presented to The Southern California Section of the Society of Naval Architects and Marine Engineers, Long Beach, Calif., May 14, 1959.*



Proposed U.S. Navy hydrofoil (PCH) patrol craft would use two 3000 hp turbines plus a 600 hp diesel. Turbines for while it's in the air, diesel when it's back in the water.

troubles. In general, difficulties encountered were not more numerous or serious than would normally be expected when introducing any new prime mover. Operating troubles and corrective actions include:

a. Bearing failures on the starting motor of one type turbines were corrected by installation of heat shields and packed bearings.

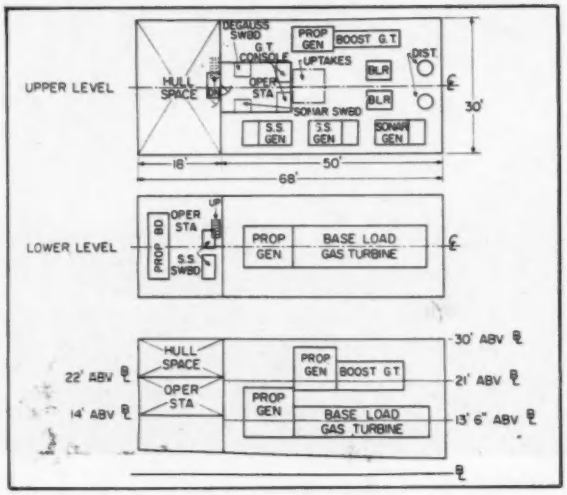
b. Accessory failures on small turbines in marine service have probably accounted for the major portion of engine downtime. These have not been confined to any one type engine or to a given application. They include clutches, microswitches, thermocouples, acceleration limiters, gears and other items. Design improvements were possible on the basis of this experience.

Marine Gas Turbine Engines on U. S. Naval Craft or to be Delivered in 1959

Engine Designation	Rating HP	Application	Craft		Number Engine Installed	Total HP Installed	Total Hrs.[1] Operating
			Type	Number			
Solar T-520	500	Emer. gen. drive	Destroyer	1	1	500	287
Solar T-520	500	Aux. gen. drive	Minesweep	2	4	2,000	3,859
Solar T-522	500	Propulsion	Landing craft	1	1	500	425
Solar T-522	500	Propulsion	Personnel boat	1	1	500	800
Metro-Vick G-2	4000	Propulsion	PT boat	1	2	8,000	172
Boeing 502-6	160	Aux. gen. drive	Minesweep	46	184	29,440	76,478
Boeing 502-8C	160	Aux. gen. drive	Minesweep	2	2	320	261
Lycoming T-53	685	Propulsion	Hydrofoil	1	1	685	100
Boeing 502-8C	160	Propulsion	Minesweep	4	4	640	1,629
Solar T-45	46	Aux. gen. drive	---	--	3	138	---
Boeing 502-10C	220	Propulsion	Landing craft	3	3	660	210
Solar T-520	500	Aux. gen. drive	Minesweep	3	6	3,000	---[3]
Boeing 502-10C	220	Propulsion	Minesweep	26	26	5,720	1,696
Solar T-522	500	Propulsion	LCPL	7	7	3,500	---[3]
Boeing 502-10C	220	Aux. gen. drive	Minesweep	28	28	6,160	376
Solar T-45	46	Pump drive	Beach lighter	1	1	46	10
Solar T-45	46	Pump drive	PT boat	1	1	46	10
General Motors GM305	225	Propulsion	Personnel boat	1	1	225	---[3]
Solar T-45	46	Air supply	Minesweep	62	76	3,496	2,632[2]
Boeing 502-10C	220	Propulsion	Personnel boat	1	1	220	30
Boeing 502-10C	46	Fog generator	Landing craft	7	7	---	---[2]
Solar T-45	46	Fire pump	Various	--	37	1,702	---
				199	397	67,498	88,975

[1] All hours as of 1 Feb. 1959
[2] All installations not complete
[3] To be delivered in 1959

Gas Turbines Spark New Marine Concepts



Compact equipment layout for craft's 2-levels.

c. Blade failures on one type turbine were particularly serious. However, this was corrected by increasing the turbine blade chord and improving combustor design. The new combustor eliminated formation of carbon which caused blade damage.

d. Inducer failures were frequent on one class generator-drive turbine. Various configurations of inducer blades are under test to eliminate this trouble.

e. A gas turbine propulsion plant in a personnel boat experienced salt fouling of the compressor during operation in rough water. This resulted in appreciable power loss. To correct this, controlled quantities of selected solids were injected into the compressor intake. While this cleaning technique was effective, the air inlet location was such that additional sea water was carried into the compressor within a short time. Based on this experience, air intakes on seven new boats were modified to minimize salt water entry to the compressor.

Looking ahead . . . .

Naval considerations of marine gas turbines now include units from 100-kw generator drives up to 15,000-shp propulsion plants for an AG Escort Ship. These craft include:

a. *Ocean escort ship, 15,000-shp.* The propulsion machinery will probably consist of a 7500-hp industrial-type gas turbine for the base load and a light-weight 7500-hp gas turbine for peak power demand. One machinery arrangement is shown.

b. *Hydrofoil patrol craft.* An artist's conception of this craft is shown. The main propulsion plant, a gas turbine, will power two shafts with a total of 6000-shp. A center shaft is fitted with a 600-hp diesel for maneuvering.

The potential of hydrofoil craft is of considerable interest at this time. The U.S. Navy and the U.S. Maritime Administration are conducting studies of such craft. Maritime has studied the feasibility of hydrofoil craft of up to 3000-ton displacement with ranges from 400 to 3600 nautical miles at speeds up to 200 knots. Specifically, one design is a 500-ton craft with 100-knot cruise speed and a 1200-mile range. The propulsion plant consists of three gas turbines with a total of 59,000-shp.

Due to a number of its characteristics, the gas turbine is in many respects superior to other engines. Some features are inherent such as simplicity and its low specific weight and space requirements. One, its non-magnetic properties, is of great interest to the Navy. Others are the result of design and development that have come far and are going ahead at an accelerated rate.

Increased attractiveness of the turbine for propulsion and auxiliary drives is due to improvement of materials, design and manufacturing techniques, combined with advances in aerodynamics. With such progress, lower first costs, improved economy and reduced maintenance are now realized.

Based on these improvements it now appears feasible to develop small turbines with overall efficiencies that are equal to the diesel through the entire operating range. Specifically, an engine in the 450-600 hp range might be produced within a period of thirty months. Such a development would cost between $2 and $8-million.

It is estimated that specific fuel consumption at 100% power would be 0.4 and at 40% power about 0.43. In order for such an engine to be competitive it should be sold for $15-$20 per horsepower and have an overhaul interval of 2000-5000 hours.

And today . . . .

Right now, gas turbines are showing real benefits in the areas of costs and performance. This is seen in developments around the world.

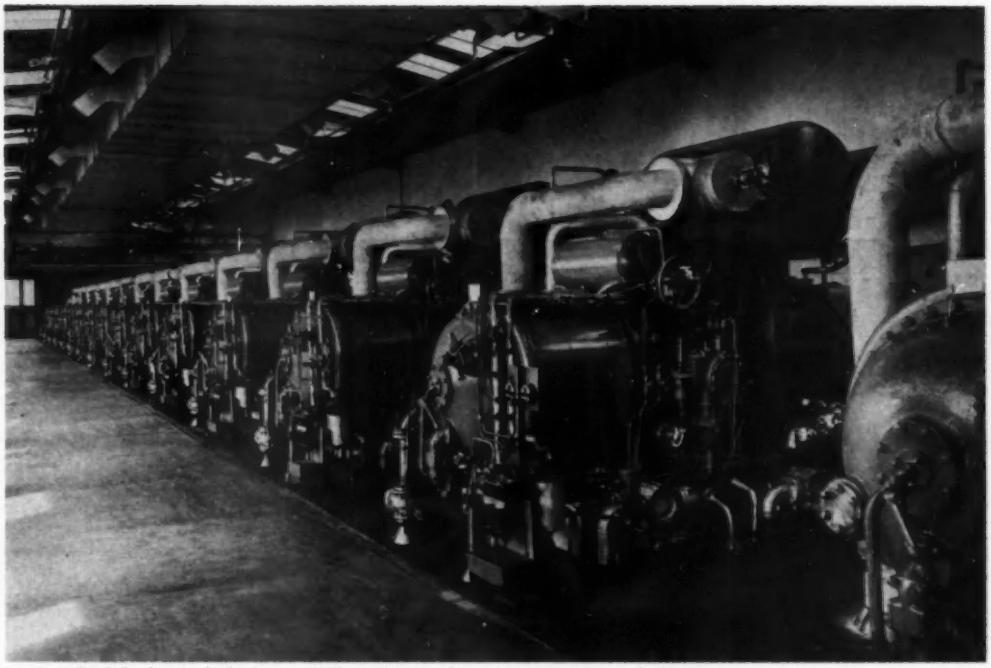
A major factor considered in a building program is that of initial cost. In a recent investigation it was determined that a particular ship could be built at less cost by using gas turbines both for propulsion as well as generator drives. In this study, steam turbines as well as diesels were compared with the gas turbine.

Marine applications of the combined type of propulsion plants are being placed in operation in rather large powers. Where peak power for maximum speed may be required, gas turbines combined with diesel or steam turbine is attractive. The British Navy is now building combined gas and steam turbine propulsion for four guided-missile destroyers and seven frigates. The Admiralty has launched a Tribal Class Frigate equipped with steam and gas turbines. The German Navy is now building six 38,000-shp diesel-gas turbine propelled destroyer escorts. The ships are two-shaft, each with two 3000-hp diesels and one 13,000-hp Brown Boveri gas turbine.

In 1947, the total gas turbine horsepower at sea was only 2500. During 1958 more than 362,000-hp in gas turbines were at sea or building for shipboard installation. This is indicative of the future trends of the gas turbine in the marine field.

FREE-PISTON ENGINES | GAS TURBINES MAKE GOOD TEAM in CHEMICAL PLANT

by J. Grindrod



Modern English chemical plant uses 15 free-piston-turbines to compress cracked gas.

ONE OUTSTANDING feature of the new olefine chemical plant which Imperial Chemical Industries Ltd. have recently brought on stream at their Wilton Works, England, is a battery of 15 free-piston gas compressors. These feed turbines that drive the rotary machines used for compressing the cracked gas before it is purified. Although free-piston-turbines have been used for generating electricity and in ships, the new olefine plant is thought to be the first industrial process to employ them.

There are several different forms of gas generators but these installed by I.C.I. at Wilton are based on the reciprocating type evolved by an Italian, the Marquis de Pescara, in the 1920's. Much fundamental development work was done in Switzerland and then later the French took it up and made a commercial success of it.

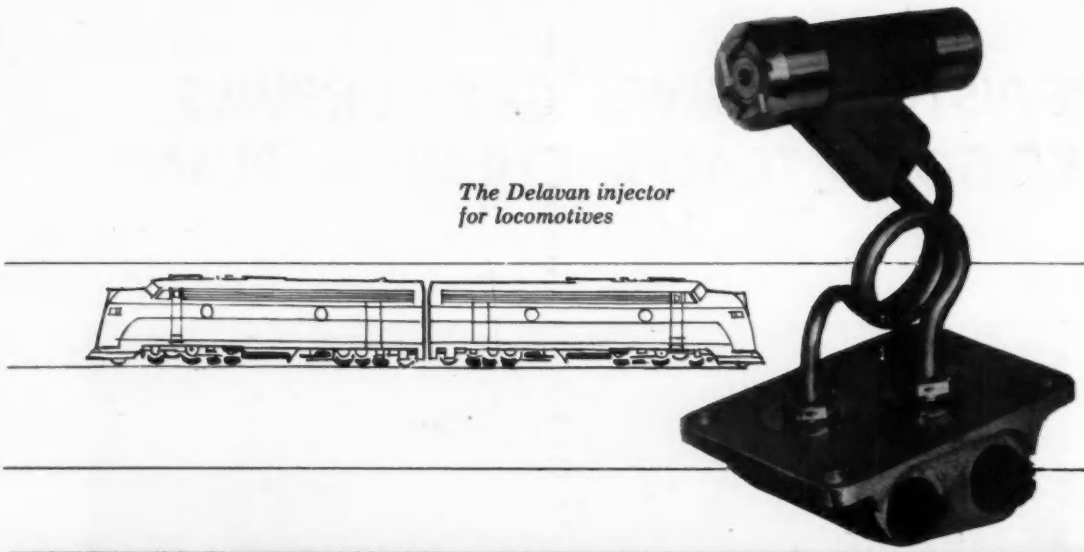
Shortly before World War II, the firm of Alan Muntz became the main licensee in Britain and in the last two or three years several British firms have taken out licenses to manufacture this type of gas generator. There are two principal sizes being made in Britain at present: a large one of 1250 hp of French design, and a small one of about one-third the power, of British design. Based on the design from the French firm of SIGMA, the generators installed at Wilton are similar in principle to the general-purpose models available, modifications being only of a minor nature.

To get a lot of hot gas at the right pressure and temperature from the oil burned, supercharging is employed. In the Pescara design, compressor pistons provide compressed air first to the engine case and then to the engine cylinder. This inward-compressing type of design differs from the outward-compressive type which other manufacturers are developing.

In the I.C.I. plant, the GS34 gas generators supply hot gas into a distributing system from which six Brush Electrical Engineering Company gas turbines are fed. The majority of gas generators furnished came direct from SIGMA in France, the remainder built by the Free Piston Engine Company of England.

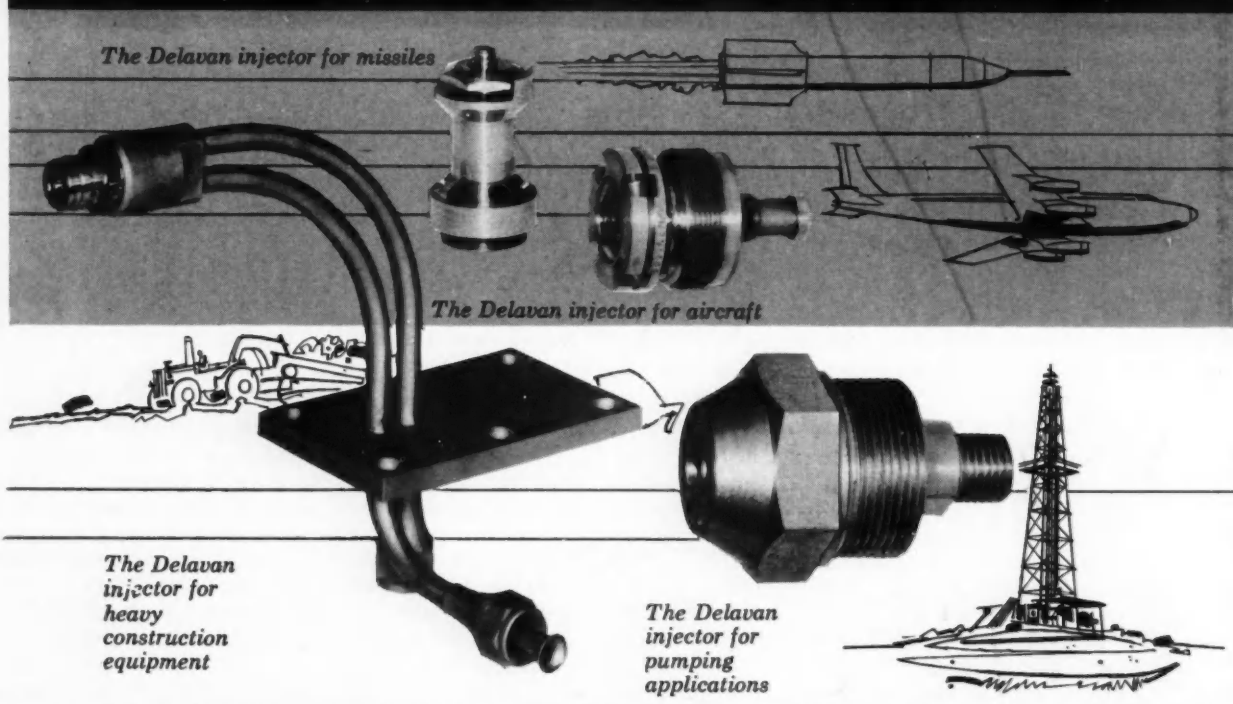
The gas turbines are well suited to drive the compressors selected as their operating speeds are the same. No intermediate gearing is necessary.

Flexibility, compactness and simplicity are reasons why I.C.I. adopted this type of power unit. Its capital cost is reasonable and it is thought that maintenance costs will be lower than for the engines previously used in other similar plants.



The Delavan injector for locomotives

IF AN EXACTING FUEL INJECTOR FOR GAST



The Delavan injector for missiles

The Delavan injector for aircraft

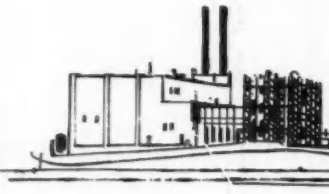
The Delavan injector for heavy construction equipment

The Delavan injector for pumping applications

Many Delavan fuel injectors are developed specially for new or unique engines. Requirements often involve a high degree of reliability for long periods of time. Injectors must be designed to perform in high and low temperature environments and handle corrosive and abrasive fuels.

When you are considering a new or difficult fuel injection application be sure to consult with us. A Delavan designed and manufactured injector may well reduce costs, save you valuable time or improve the performance of your equipment.

Delavan can bring a fund of developmental experience and man-

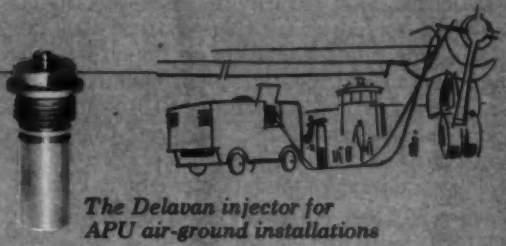


The Delavan injector for power plants

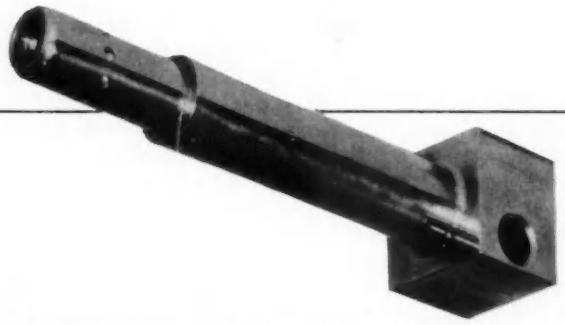
The Delavan injector for marine engines

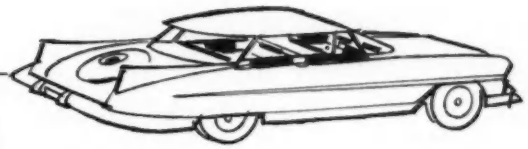
AS TURBINE ENGINES IS NEEDED . . . SO IS DELAVAN

The Delavan injector for helicopters



The Delavan injector for APU air-ground installations





The Delavan injector for automotive applications

ufacturing know-how to your fuel injection problems . . . know-how that is unparalleled in the industry. Delavan is the world's largest manufacturer devoted exclusively to the design and manufacture of fuel injectors and spray nozzles.

DELAVAN
Manufacturing Company
WEST DES MOINES, IOWA

APU's...

Aviation Utility Outfielders

Without APU's (auxiliary power units) today's aviation would practically be grounded. Small, rugged, versatile—they catch all the vital auxiliary jobs batted their way. Here are some major ones . . . what they are . . . what they do.

AiResearch truck containing GTCP-91 turboshaft-compressor supplies electric power, air conditioning for jet airliners.

GAS TURBINES for auxiliary purposes—as distinct from those for propulsive purposes—are used extensively in connection with aircraft in the air and on the ground. In the United States, leading manufacturers of these relatively small but important APU's (Auxiliary Power Units) are AiResearch Manufacturing Company of Arizona, a division of The Garrett Corporation; Allison Division of General Motors Corporation; Boeing Airplane Company; Continental Aviation and Engineering Corporation; Curtiss-Wright Corporation; and Solar Aircraft Company.

These APU's are of three basic types—turboshafts used for driving electric generator sets, pumps and other equipment; turbo-compressors supplying compressed air for starting main gas turbines and for air conditioning; and combination turboshaft-compressor units giving shaft power and/or pneumatic power for various aviation purposes.

Ranging in power outputs from 5 shp to more than 500 shp, and with outputs from 1.5 lb to 3.5 lb of air per sec, these APU's are used primarily in mobile ground vehicles for engine starting and servicing and for airborne electrical generator sets. They are light in weight, embody integral lubrication and cooling systems, and have fully-automatic or semi-automatic controls. They use aviation gasoline, combat gasoline, automotive gasoline, kerosene, and jet fuels, and are quite economical for the work they do.

AIRESEARCH

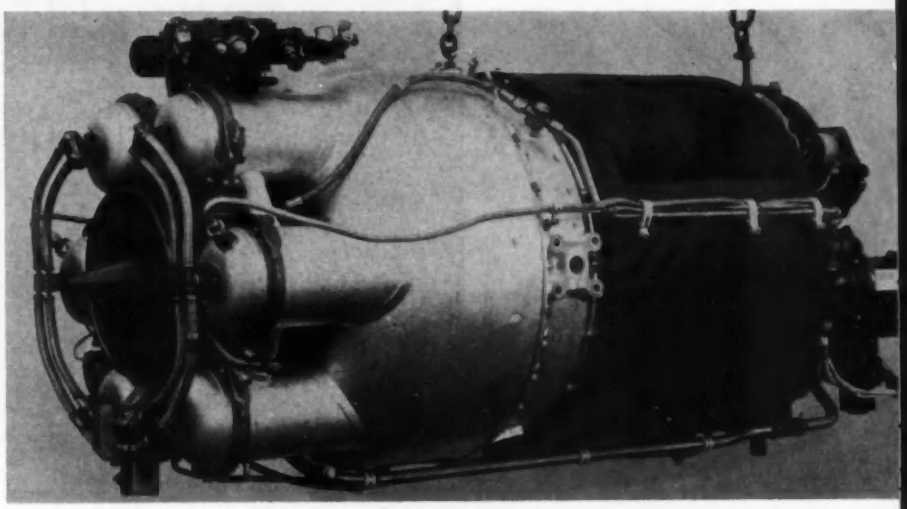
AiResearch Manufacturing Company states that it has built more than 8500 APU's since 1945, which makes it the largest manufacturer of this kind of aviation equipment in the world. Its gas turbines are used extensively on military and commercial aircraft, and for mobile ground installations. Most of these turbines have a 2-stage centrifugal compressor, a reverse-flow combustion chamber, and a 1-stage radial-inflow turbine.

Smallest AiResearch gas turbines are those of the GTP 30 turboshaft series with a 1-stage centrifugal compressor. The GTP 30 and GTP 34 units weigh 45 lb and are rated 38 shp and 54 shp at 52,800 rpm continuous. The GTCP 30 and GTCP 34 turboshaft-compressor variations of the series are rated 16 shp and 26 shp, respectively, plus 0.17 lb of bleed air per sec continuous.

GTP 70 series turboshafts have a 2-stage compressor. The GTP 70-10 unit weighs 190 lb and gives 100 shp at 40,800 rpm at 59°F ambient temperature. It uses 126 lb of fuel per hr. Other models of this series, rated from 70 shp to 150 shp, are used to drive 30-kw, 45-kw, and 60-kw d-c electric generator sets.

In the turbo-compressor field, various models of the GTC 85 series are available. The GTC 85-71 unit, providing bleed air from an oversize compressor, is rated 181 air hp and has a continuous output of 2.1 lb of bleed air per sec at 42,000 rpm. It weighs 217 lb and consumes 230 lb of fuel per hr. It is used for starting the Allison T56 turboprops on the Lockheed C-130 Hercules transport and for engine check-out, de-icing and ground air-conditioning.

The AiResearch GTC 85-37 unit used on the Grumman Gulfstream executive transport provides electric



AiResearch GTCP 105-6 turboshaft-compressor unit provides pneumatic power for starting jet engines on Convair B-58 supersonic bombers.

power from a belt-driven 50-kw d-c generator to start the main engines, and pneumatic power to air-condition the cabin. Other models have bleed air flows from 1.9 to 2.4 lb per sec and weigh from 185 lb to 225 lb. They are operational to 30,000 ft.

The GTU 85-3 turboshaft-compressor airborne unit provides shaft power and pneumatic power simultaneously and it can also utilize bleed air from the main engines of the aircraft to increase its own output. It is rated 120 shp or 1.8 lb of bleed air per sec at 42,000 rpm continuous. Its combined rating is 35 shp plus 1.53 lb of bleed air per sec. It weighs 333 lb and uses 240 lb of fuel per hr.

The AiResearch GTCP 85-97 turboshaft-compressor unit, not equipped to use additional air, weighs 260 lb and uses 220 lb of fuel per hr. It gives 200 shp or 1.93 lb of bleed air per sec at 40,800 rpm. Its combined output is 50 shp plus 1.58 lb of bleed air per sec. It can be airborne or truck-mounted, driving a 60-kva a-c alternator. The GTCP-91 commercial version is used in panel trucks for air conditioning and starting the engines of large jet airliners.

Largest turboshaft-compressor unit is the GTCP 105-6 which is of entirely different design from other AiResearch APU's. It has a 2-stage centrifugal compressor, 6 reverse-flow combustion chambers and a 2-stage turbine embodying radial-inflow type and axial-type wheels. It weighs 365 lb and uses 400 lb of fuel per hr. It is rated 438 air hp or 3.5 lb of bleed air per sec at 35,140 rpm. It is trailer-mounted and provides pneumatic power for starting General Electric J79 turbojets on the Convair B-58.

ALLISON

Allison Division is testing a lightweight turboshaft that can be used as an APU. This is the Model 250-C6, intended for ground-support and airborne power supply. It is identical in basic construction with the Model 250-C2 turboshaft now under development for helicopters and flying "jeeps" for the U. S. Army and the U. S. Air Force.

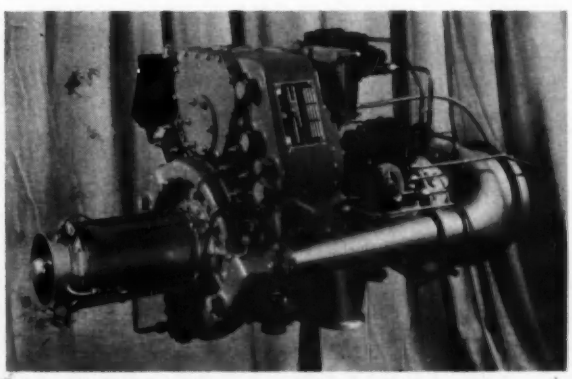
Constructionally, Model 250-C6 has a 7-stage axial compressor, a 1-stage centrifugal compressor, a reverse-flow combustion chamber, a 1-stage gas generator turbine and a 2-stage free power turbine driving a 6000-rpm output shaft with fore and aft female splines. Control system is of the hydro-mechanical type, with a power turbine speed governor and a torque limiter. The engine uses 155 lb of fuel per hr and weighs 106 lb. It has a continuous rating of 212 shp at 29,830 rpm.

BOEING

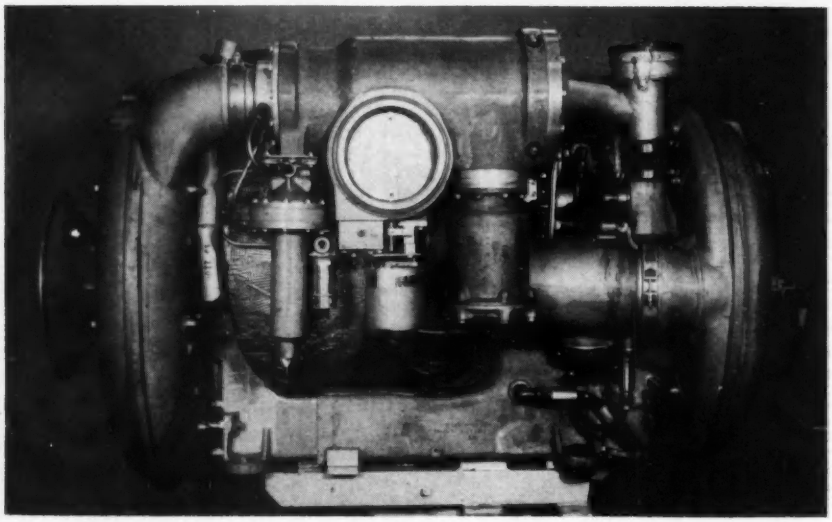
Boeing Airplane Company's current APU is its Model 502-11BA turbo-compressor. It has a 1-stage centrifugal compressor, 2 combustion chambers, a 1-stage gas producer turbine, and a 1-stage free power turbine which drives a separate 1-stage output compressor. It weighs 410 lb and consumes 254 lb of fuel per hr. It is rated 205 air hp and gives 2.1 lb of air per sec at 36,000 rpm continuous. This unit is used in mobile installations for starting main engines and checking pneumatic systems of large jet aircraft. According to Boeing, more than 900 gas turbines have been produced by its Industrial Products Division for military and commercial purposes.

CONTINENTAL

Continental Aviation and Engineering Corporation has been in production with its Model 141 turbo-compressor for the past five years. During this time, more



Allison 250-C6 turboshaft can provide power for ground support and airborne power supply units for commercial and military aircraft.



Boeing 502-11BA turbo-compressor in mobile installations is used for starting main engines and checking pneumatic systems of jet aircraft.

than 1000 of these APU's have been supplied to the U. S. Air Force for starting large turbojets and turboprops on military aircraft. The unit is mounted in MA-1 (TC-104) and MA-1A (TC-106) mobile and portable starter carts. It is also used for starting jet engines on commercial aircraft, for cabin air conditioning and driving a-c alternators.

Model 141 gas turbine has a 1-stage centrifugal compressor, radial and axial diffusers, an annular combustion chamber, and a 2-stage turbine. The fuel is atomized into the combustion chamber from a rotary distributor mounted on the hollow main shaft. Mechanical-type automatic controls include an acceleration control, a constant-speed governor, and a pressure regulator mounted in an enclosed "control island" on the nose of the engine. The unit weighs 241 lb and has a fuel consumption of 287 lb per hr. It is rated 191 air hp at 35,000 rpm, continuous, with an output of 2.2 lb of bleed air per sec.

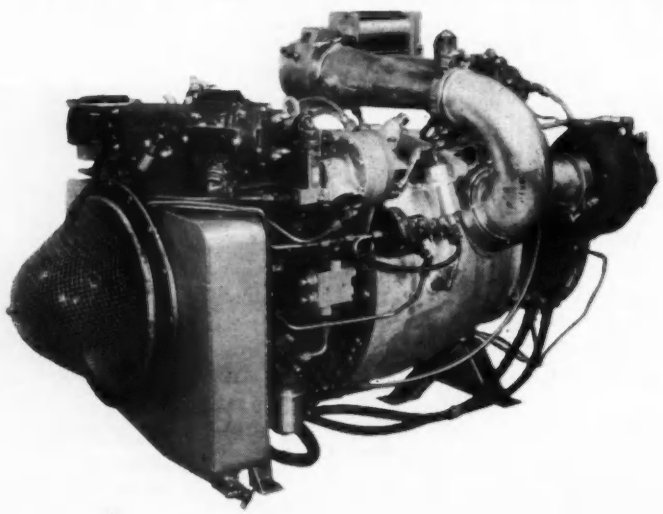
CURTISS-WRIGHT

Curtiss-Wright Corporation has recently built what may be the smallest APU for aviation. Developed by its Santa Barbara Division, this miniature gas turbine known as the Turbo-Mite is being tested by the U. S. Army as a portable electric power unit. It has a single-entry centrifugal impeller mounted back-to-back with a radial-inflow turbine wheel on an ungeared shaft and an annular reverse-flow combustion chamber. With integral oil sump, it is approximately 10-in. in diameter and 12-in. long. It has a weight of 35 lb and is rated 5 shp at 24,000 rpm continuous. The turbine unit being tested is direct-coupled to a 2.5 kva 400-cycle a-c alternator.

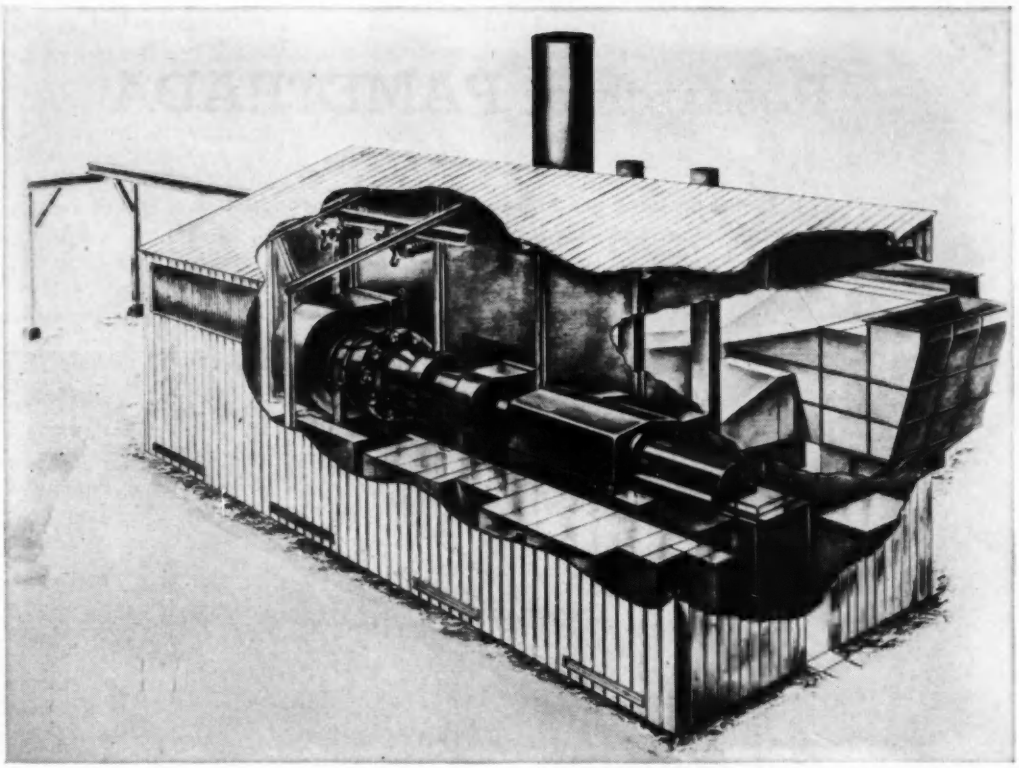
SOLAR

Solar Aircraft Company's latest APU is the Titan T-62T turboshaft. It has a 1-stage centrifugal compressor, a combustion chamber of annular reverse-flow type and a 1-stage radial-inflow turbine. A reduction gear-box with 8000-rpm output shaft is mounted at the front of the unit. It weighs 60 lb with gearbox and is rated 80 shp at 56,700 rpm continuous. Fuel consumption is 88 lb per hr.

Other Solar APU's include 50 shp Mars T-41 M Series turboshafts that are used to drive a-c alternators or d-c generators on the ground and in the air; and the Jupiter T-300J turboshaft-compressor unit that can drive a 90-kva a-c alternator or a 90-kw d-c generator, or deliver 2.5 lb of bleed air per sec at 20,600 turbine rpm.



Continental Model 141 turbo-compressor mounted in mobile cart supplies bleed air for starting large military jet engines for U.S. Air Force.



Westinghouse single unit gas turbine peaking plant.

Westinghouse Gas Turbines...

A NEW DIMENSION IN PEAKING POWER ECONOMICS

Westinghouse has developed a complete 22/27.5-mw gas turbine peaking plant to fulfill the increasing peak load generation problem of America's growing utility systems. These minimum first cost plants can save you money due to the reduction in capital expenditures during the period when Westinghouse gas turbines are utilized for peaking power generation rather than adding the next large size—more expensive—base load unit to the system.

Here are several factors affecting its over-all economics:

Lowest Plant Cost. The complete gas turbine peaking plant capable of producing 22 mw up to an ambient temperature of 100°F can be installed for $110/kw. At 40°F the plant output increases to 27.5 mw and the installation cost decreases to $95/kw.

Lowest Operating Cost. The complete plant may be remotely operated, thereby minimizing cost of operating labor.

Lowest Transmission Cost. The flexibility of location of this power plant can minimize transmission system investment as much as $50/kw.

Let us prove that Westinghouse gas turbine peaking plants are the most economic method of generating peaking power capacity. Call your Westinghouse representative or write Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh 30, Pennsylvania.

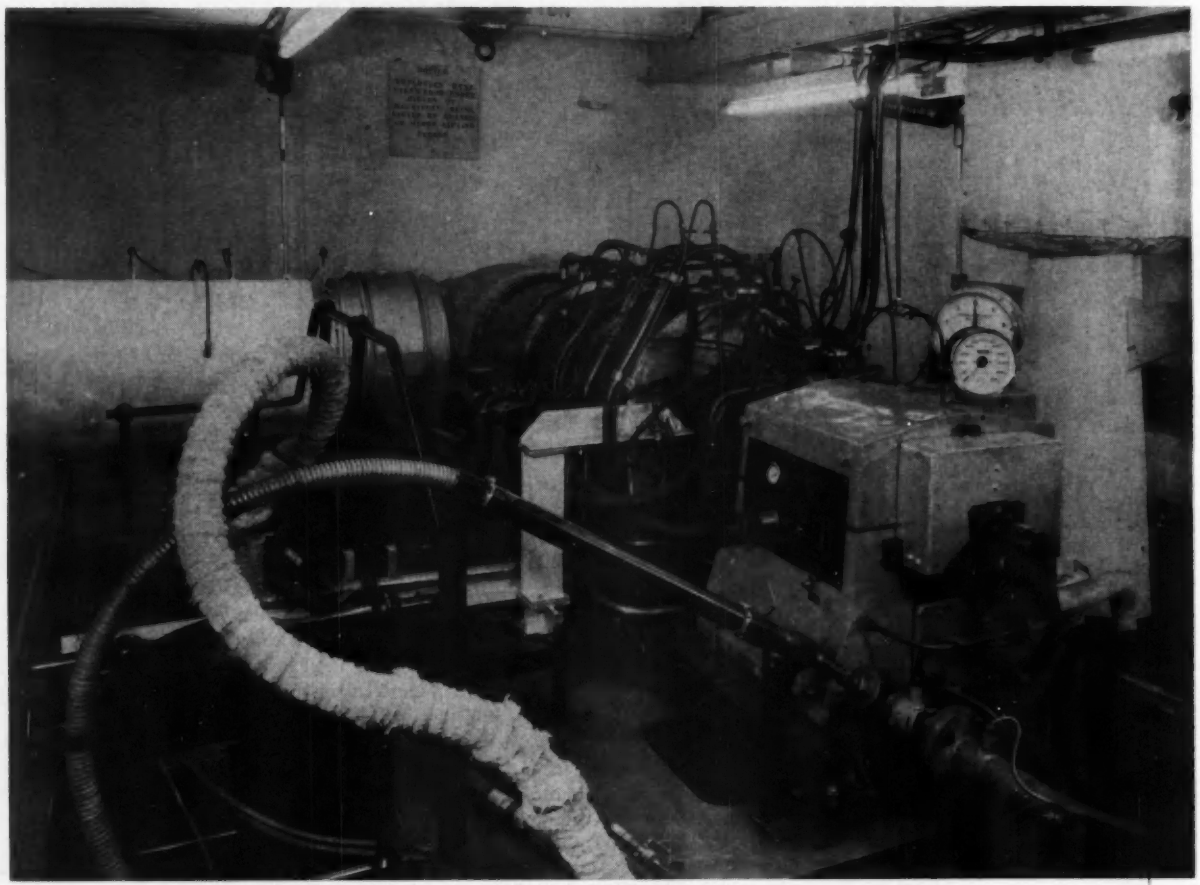
J 50613

YOU CAN BE SURE... IF IT'S Westinghouse

Be sure to visit our exhibit booth, No. 9 at the ASME show, Rice Hotel, Houston, Texas—March 6-9.

Research at PAMETRADA

A report on some gas turbine projects being conducted at this important British research facility.



Liquid-cooled turbine and brake in test cell. It's had 50 hr of operation, some at 2200°F. Liquid-cooling appears to improve operating life, lower fuel consumption.

IMPORTANT research work in the area of gas turbines is being conducted at PAMETRADA Research Station, the full name of which is Parsons & Marine Engineering Turbine Research and Development Association. Director Dr. T. W. F. Brown has given permission to report on some of the more important projects under way.

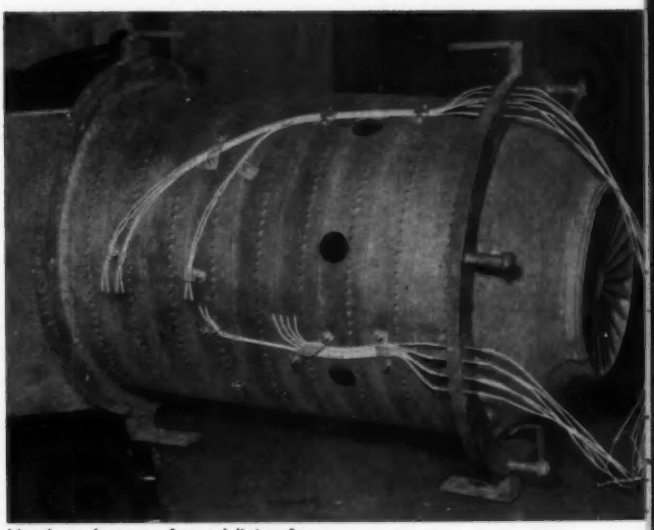
A Liquid-Cooled Turbine Project

Over 50 operating hours have been logged on a liquid (NaK) cooled, single-stage turbine. Of this time, 50 minutes were at the maximum turbine inlet temperature of 2200°F. Remainder of the time was on the following schedule: 4½-hr at 1750°F; 22-hr at 1250°F; and ½ hr each at 1970°F and 2100°F. Ability of the turbine to live for close to two hours at the 2000-2200°F level shows promise for liquid cooling of this type as a means of extending operating life at elevated temperatures and thus reducing specific fuel consumption. The turbine-dynamometer setup is illustrated. (Air-cooled blades are also being investigated by a test rig but data is not yet available.)

Test By-Product—
New Approach to Instrumentation

A cooled-surface test rig, part of combustion chamber development, produced an interesting and useful approach to instrumentation. It was found that temperature of the test surface at any distance from the cooling air inlet could be correlated with cooling air flow and temperature as well as gas temperatures.

Of course, these results only applied for the given geometry of the specimen and the heat source, in this case a refractory-lined duct. However, possibilities offered to monitor flow and temperatures are so attractive that two other specimens have been made and are awaiting test. One, the metal lining for a combustion chamber, is shown with thermocouples in place.



Here's a close-up of metal lining for combustion chamber with thermocouples installed.

Low-Cost, High-Temperature Flame Tube

An experimental refractory-lined flame tube, consisting of relatively small bricks, held flexibly in sheet-metal channels supported on a framework of mild steel, has been assembled and tested. After fifteen hours operation at 700°F inlet and 2200°F outlet temperature the bricks and their holding channels have not been affected.

Testing Ceramic Blades For High Temperatures

Ceramic blade investigation includes graphite specimens coated with a silicon-chromium alloy. These have been tested in a gas-fired rig and the coating was found to break down after a few hours at 2200°F. Two samples of silicon nitride were tested and found to have less resistance to creep at 2200°F than the best of the other grades of silicon nitride and silicon carbide that had been tested earlier.

Heat Exchangers Investigated to Improve Economy

Heat exchanger testing was conducted, using "Vanilla"-type fuel oil with kaolin and 1% sea water added, until a total of 2022 hours at steady conditions was reached. Soot-blowing trials using a steam accumulator were carried out during the last 100 hours and resulted in the removal of a large amount of deposit. Three soot blows restored the gas-side pressure loss to its original value. Tube stack with cover removed after a long run is shown. Examination showed that fouling and corrosion of the tubes was negligible.

Free-Piston Turbine Plants

Five inquiries have been received for gas turbine free-piston plants. Turbine plans have been issued by PAMETRADA for one. Turbine power ranged from 220 kw to 7000 shp and the gasifier being considered for each was the Sigma GS. 34. All of the turbine designs have five stages of reaction blading. In the larger powers, disc and diaphragm construction is used. Glands are a combination of metal labyrinth and carbon labyrinth types and are designed so that only a low-pressure supply of sealing air is required. Particular attention has been paid to the design of turbine inlets. These are of the symmetrical type with a single entry and full admission to the blading.

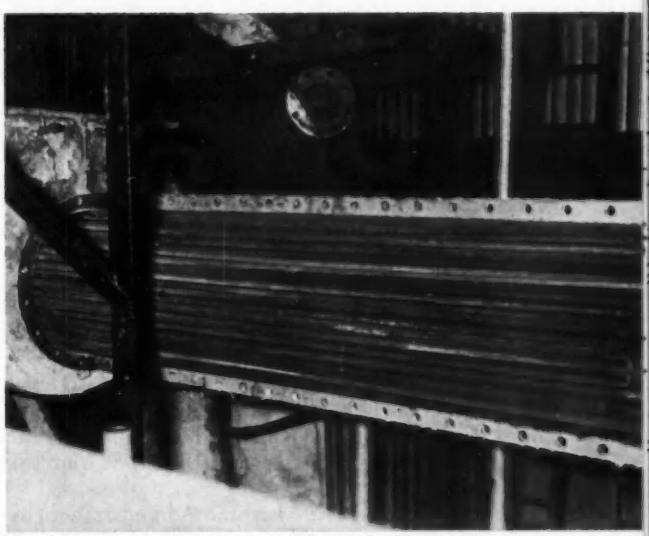
Method of Reversing

Where turbines are for main propulsion, the question of the best means of going astern has yet to be resolved. Three methods are being considered.

1. Using an ahead turbine and also a reversing turbine. The reversing turbine is a 2-row Curtis wheel, housed in a separate casing.

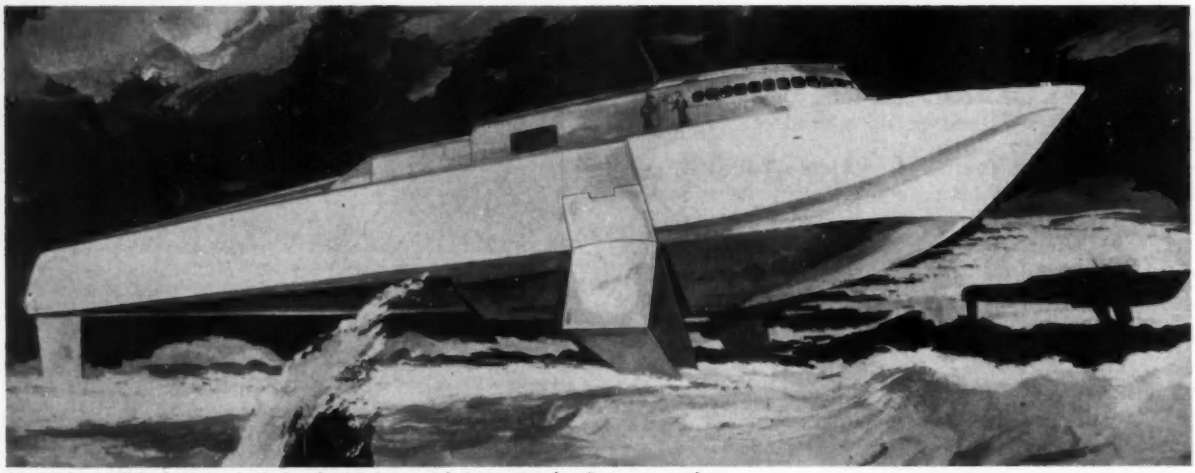
2. Using an ahead or uni-directional turbine only. In this case the uni-directional turbine drives either through reversing gear or through controllable-pitch propellers.

3. Use of an inward radial-flow turbine with adjustable nozzle vanes, vane position determining direction of rotation. This is being investigated and a 2000-shp turbine design is being prepared. This turbine will operate at about 15,000 rpm and will drive through epicyclic gearing.



This shot of heat exchanger shows tube stack with cover removed. It's just finished a long run on Vanilla fuel with 1% sea-water and kaolin added.

Gas Turbines to "Fly" 80-ton Hydrofoil



Here's how it'll look. Being built for the Maritime Administration by Grumman and Dynamic Developments, a gas turbine will "fly" hydrofoil at speeds up to 80-knots.

Large, high-speed hydrofoil craft are moving from the "dream" stage to reality with design and construction of a 80-ton, 60-80 knot ship under way. "Punch" for all operating conditions comes from light-weight, high specific output gas turbines.

AN 80-TON, 60 to 80-knot, open-sea hydrofoil craft powered with a 17,000-hp gas turbine is now under design. This is to be an all-gas turbine ship. Propulsion power, both for flying and displacement conditions, is supplied from two gas turbines. Electric power will be from a small gas turbine-driven generator.

The ship, with an all-aluminum hull, has an over-all length of 104 feet, draft with foils retracted about 6 feet, and a beam of 21½ feet. The craft, an artist's conception shown, is to be launched in June, 1961. Design and construction is being done by Grumman Aircraft Corporation's affiliate, Dynamic Developments Inc. under a $1.5-million contract with the U. S. Maritime Administration.

It is considered by the Maritime Administration Research Coordinator that "the craft represents one of the most significant advances in marine transportation in the past five decades."

Early Hydrofoils

A hydrofoil craft includes the hull, foils, or underwater wings, and supporting structure between the foils and hull. Dynamic lift of the foils while under way brings the hull clear of the water. The hydrofoil is not new. Work was done on this conception by a number of people around 1900.

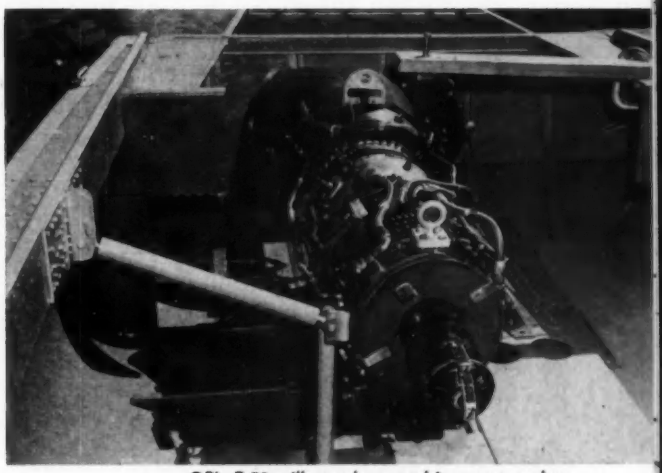
A catamaran, equipped with four transverse hydroplanes, was operated in France by Comte de Lambert in 1897. This craft may have been flown by planing action instead of hydrofoil lift. Crocco, an Italian, operated a craft, a monoplane with dihedral foils, at a speed of 50 mph about 1900. Others, including the Wright Brothers and Alexander Graham Bell, were active in hydrofoil investigations at the turn of the century.

Recent Turbine Hydrofoils

The gas turbine-powered HALOBATES has been the basis of a U. S. Navy hydrofoil program. The HALOBATES is a 15-ton converted LCVP driven by a Lycoming T53-L-1 gas turbine through an over-stern transmission. The gas turbine propulsion package resulted in a weight-saving of about 2000 pounds or 6½% of the design gross weight,

U. S. Army Ordnance Corps hydrofoil investigation includes the conversion of a World War II DUKW to a hydrofoil craft. A Lycoming T53-L-1 gas turbine power package was installed in this vehicle. In flight, the FLYING DUCK is capable of speeds in excess of 40 mph. (See January-February, 1960, GAS TURBINE, Pg. 10).

Office of Naval Research has had an active hydrofoil program for several years. Grumman investigated feasibility of hydrofoil sea craft as a means of high-speed transportation. The latest installation made by Grumman is a General Electric T-58 gas turbine in a 23-ft., 65-knot hydrofoil craft as part of its recent investigations. The T-58 propulsion unit in this craft during construction is shown.



GE's T-58 will supply propulsion power when craft "lands" back in the water. Engine has been already used in 23 ft, 65-knot hydrofoil.

80-Ton Hydrofoil

This ship was based on results of feasibility and design studies conducted by Grumman and Dynamic Developments over the past two years. The contract is a joint government and industry-financed project with industry participation by Dynamics and its associates, plus General Electric. Designed to operate in the open sea, the ship will be powered by a conversion of an aircraft-type gas turbine.

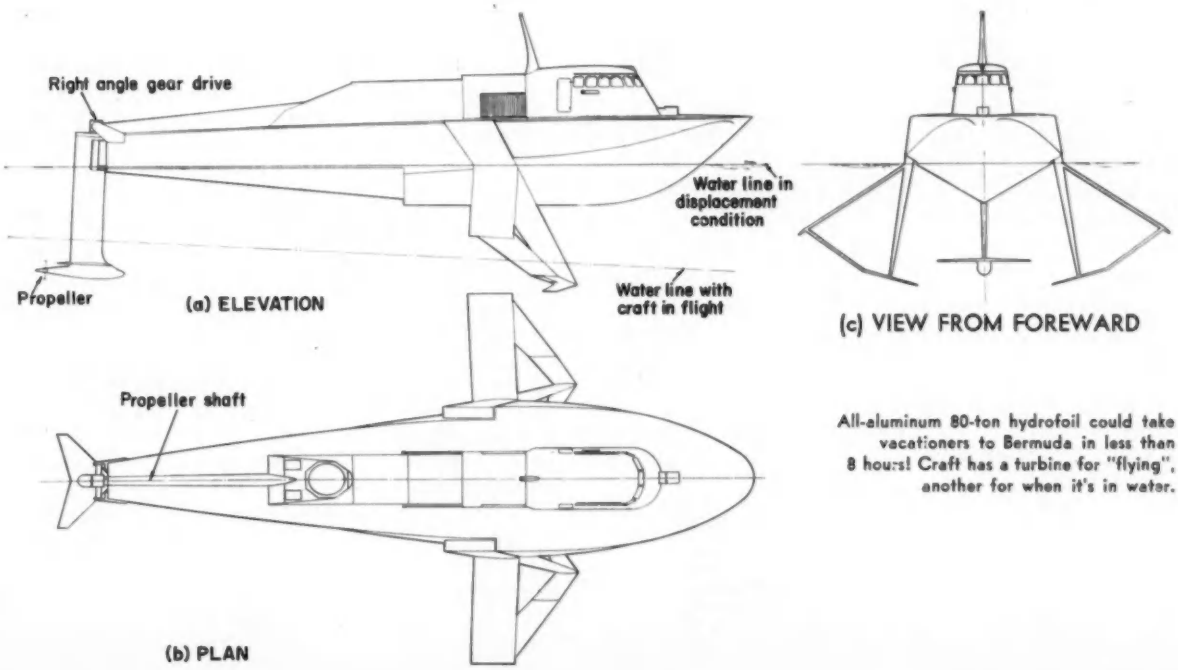
Construction of the all-aluminum hydrofoil ship is expected to start soon for June, 1961, launching. A test program will be conducted to demonstrate its guaranteed speeds and all-weather open-ocean capabilities. The ship will permit less than an 8-hr running time between New York and Bermuda.

In principle, purpose of the hydrofoil system is to reduce the wetted area of the ship's hull at high speed. It also keeps the hull entirely clear of waves when operating in rough water. This makes it possible for the craft to travel at high speeds in both smooth and rough water with reasonable power applied.

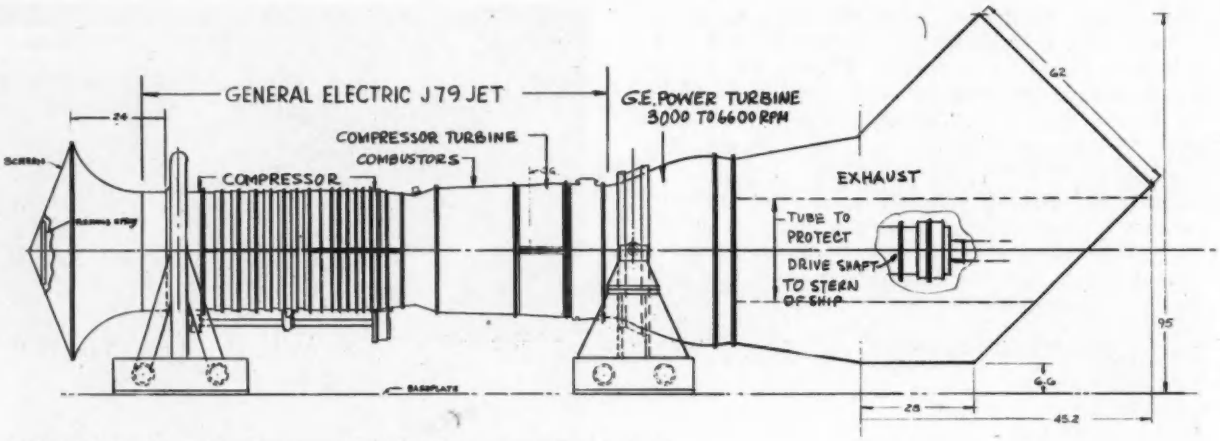
This design has the main foils or "wings" located just forward of the center of gravity and a smaller foil well aft of the center of gravity. Quick damping and stability in rough water results in smoother rides and excellent maneuverability at high speeds. Particulars on the ship are included in Table 1.

All-Gas Turbine Ship

Propulsion plant for the high-speed, foil-borne condition will consist of a General Electric J-79 aircraft gas turbine acting as a hot gas producer to drive the power turbine. This turbine will be located on the main deck just aft of the pilot house. Combustion air will be drawn through separators to minimize the quantity of salt water entrained in air to the compressor. The en-



All-aluminum 80-ton hydrofoil could take vacationers to Bermuda in less than 8 hours! Craft has a turbine for "flying", another for when it's in water.



GE's 17,000-hp J79 produces hot gases for hydrofoil's power turbine. Sucked in salt spray is removed by separators . . . compressor blades can be washed down.

gine is placed with the compressor bell-mouth facing forward. Exhaust is directed aft and upward.

From the 17,000-hp power plant, the main shaft runs aft along the main deck to a right-angle transmission, down to another right-angle gear box and the propeller. Time between overhauls of the turbine is estimated at about 2500 hours. Water spray rings will be incorporated in the compressor inlet to permit washing of compressor blades and stators to remove salt deposits resulting from any entering sea water.

During operation in a displacement condition, nonflying, a General Electric T-58 gas turbine will supply propulsion power. This power plant will be located aft in an auxiliary machine space. Electric power while under way and alongside a dock will be supplied from a small gas turbine APU (auxiliary power unit).

More Gas Turbine-Hydrofoil Ships in Prospect

Studies have been made on larger hydrofoil ships with gas turbine propulsion. For example, a 500-ton, 76-knot craft with a total of 45,000-hp propulsion gas turbines has been investigated. Details on this craft are listed on Table 2.

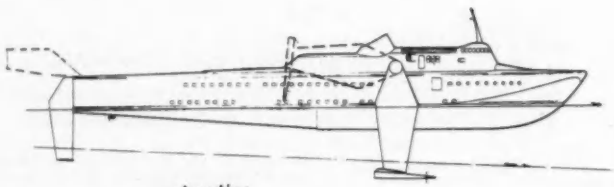
One thing is sure, the characteristics of gas turbines make them highly suitable for craft of this type. Also, the low specific weight and volume of the aircraft-type gas turbine makes this prime mover uniquely suited for high-speed commercial and military hydrofoils.

TABLE 1
DETAILS OF 80-TON HYDROFOIL SHIP

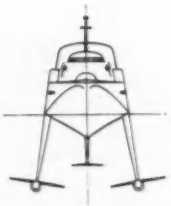
Length, overall	104 ft, 0 in.
Length, water line	95 ft, 10 in.
Beam, water line	21 ft, 6 in.
Draft, foils down	19 ft, 9 in.
Main propulsion engine	GE J-79 free power-turbine version
Displacement propulsion engine	GE T-58
Design speed, guaranteed	60 knots
Design displacement	80 tons
Estimated useful load (payload + fuel)	29 tons
Range (foil-borne 10-ton payload, 10% reserve)	655 n. miles

TABLE 2
DETAILS ON 500-TON HYDROFOIL SHIP

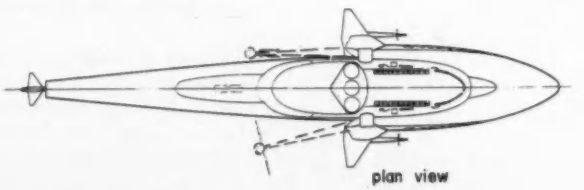
Length, overall	249 ft, 9 in.
Length, water line	225 ft, 0 in.
Beam, water line	54 ft, 8 in.
Speed, foil-borne	76 knots
Number gas turbines for foil-borne propulsion	3
Total Power, gas turbines, foil borne	45,000 hp
Power, gas turbine, displacement	4,400 hp



elevation



view from foreward

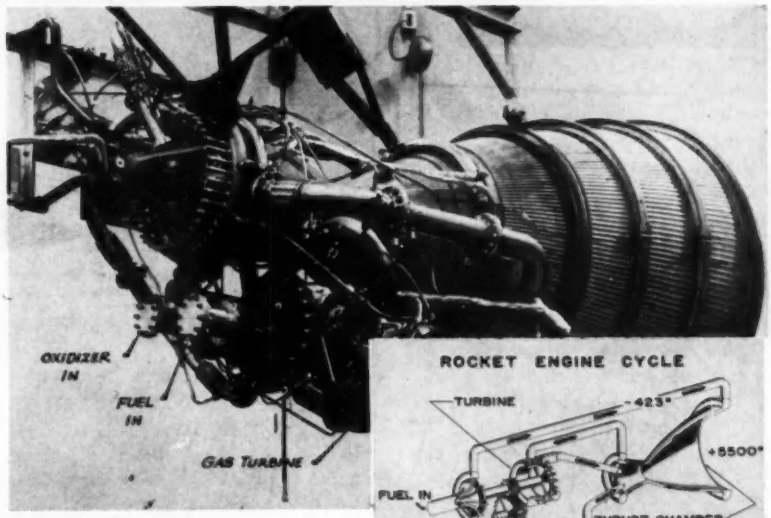


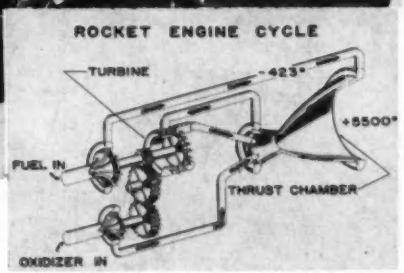
plan view

Big 500-ton hydrofoil craft uses three gas turbines totaling 45,000 hp. It's speed will be 76-knots.

Novel P&W Turbopump Increases XLR 115 Efficiency

Nation's first liquid hydrogen rocket engine—Pratt & Whitney's XLR 115—opens up new fields for missiles and space vehicles. P&W's engine incorporates a novel gas turbine pumping cycle. Eliminating need for an auxiliary gas generator, XLR 115 gets its pumping power directly from the gas turbine by utilizing expanding hydrogen. Fuel plays two roles in the XLR before it is burned. It drives the turbopump and it cools the thrust chamber and nozzle.





Here's how it works . . .

Liquid hydrogen is pumped into the cooling jacket at -423°F. Inside the thrust chamber it is burned with oxygen at 5500°F. Hydrogen in the cooling jacket picks up heat and is converted to a gas, furnishing power to pump more liquid hydrogen and liquid oxygen into the system.

P&W's unique system means fuel need not be by-passed to feed an auxiliary pump turbine. All fuel for the XLR is burned only in the thrust chamber where it produces useful thrust. P&W says their new turbopump simplifies the engine, increases its efficiency . . . permits lower fuel tank pressures, allows extremely lightweight tanks. Capable of carrying two to three times the payload of conventional fuels, liquid hydrogen-burning XLR 115 has been picked to power the Centaur and an upper stage of Saturn.

("Whirlfire"—*Continued from page 19*)

pressure drop, important for maximum efficiency. Another advantage of the drum-shaped regenerators is the fact that all hot gases and hot working parts of the engine are contained within the regenerator drums. The regenerators serve as insulating blankets to keep not only the heat but most of the characteristic turbine noise from reaching the outside of the engine.

These basic engine features have been combined with improved component and structural design to make the GMT-305 engine a significant step forward in efficiency, compactness, lightness, and applicability.

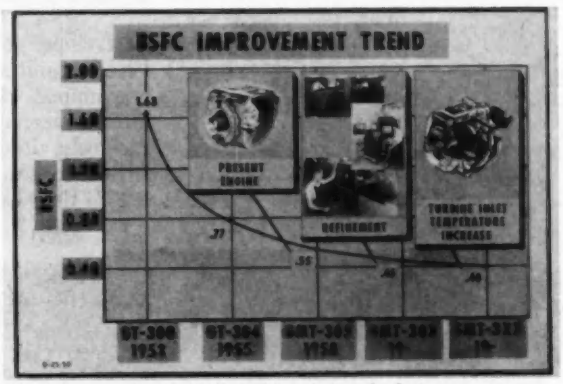
Performance Characteristics—Today and Tomorrow . . .

Basic engine performance characteristics are such that approximately full power is available over a wide speed range. This feature permits utilization of a simplified transmission.

The "Whirlfire" engine, because of the free-turbine concept, has the capability of operating with the output shaft stalled. At this condition, output torque is approximately double the torque available at full power. Consequently, rapid application of load is possible without detrimental affects on engine operation.

Specific fuel consumption values are the result of applying the principle of regeneration and are roughly half the SFC figures for a non-regenerative gas turbine. Another noteworthy characteristic is the flatness of the curve at the mid-power range.

Fuel economy of the 300 Series gas turbine engines



What's happened with GM's turbine during the last seven years . . . and what's looked for in the not too distant future.

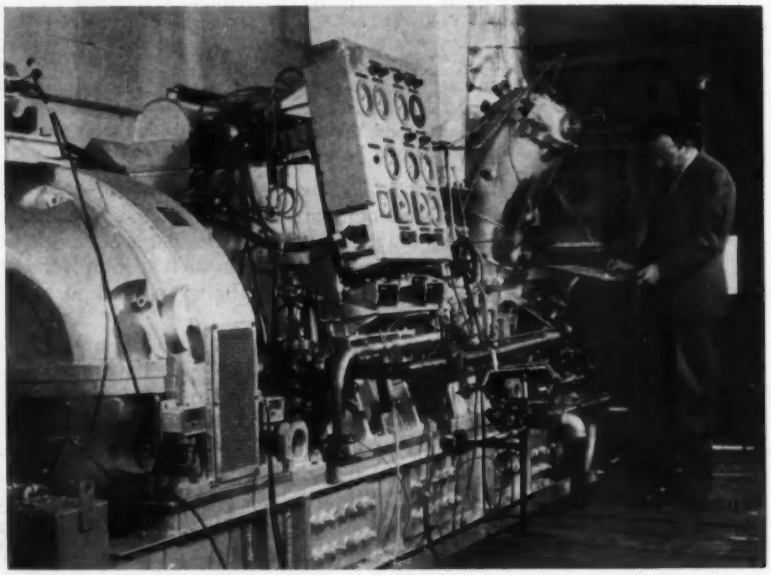
was improved when the regenerator was incorporated and with design refinements incorporated in the later engine. The 0.45 bsfc point is attainable with further refinements in component design such as improvements in compressor and turbine efficiencies and in regenerator effectiveness.

The last point on the chart utilized these improved components in a thermodynamic cycle having a higher temperature limit. The predicted 0.40 bsfc, when realized, will be more economical than the best vehicular compression ignition—torque converter combination having equivalent output characteristics. Progress that has already been made in the relatively short development life of the vehicular gas turbine leaves little doubt that this goal can be attained.

GT PRODUCT NEWS

Mobile two-in-one ground unit . . .

Developed jointly by Boeing Industrial Products Division and General Electric, unit supplies both pneumatic and electrical power. Panel truck is equipped with a Boeing gas turbine-driven compressor to supply air for commercial jet transport engine starts and a General Electric 60-kva 440-cycle alternator that supplies electrical power during commercial jetliner loading operations. Alternator is driven from power take-off on engine that drives truck.



250-KW Gas Turbine-Powered System

This 250-kw gas turbine-powered system will be installed aboard a US Navy mine sweeper. Built by Tapco of Thompson Ramo Wooldridge for the Bureau of Ships, it is designed to furnish alternating current at frequencies from 10-60 cps. Prime mover is a specially-built English 430-hp gas turbine engine manufactured by Ruston and Hornsby. System includes engine, reduction gearbox, magnetic clutch, 250-kw generator and a control panel mounted on a bedplate. Generator is at left, turbine at far right.

Sales Skyrocket For Ball Valves

The valve industry is in for a revolution. From a standing start a few years ago, precision ball valve sales to industry rose to $5-million in 1959. This equalled purchases in that year by military agencies for whom the precision ball valve was developed, according to Bernard L. Moss, President, Hydromatics, Inc., manufacturers of Flo-Ball valves.

Precision ball valves offer 100% flow efficiency, low torque operation and zero backlash. Reaction Motors uses them as standard on their XLR-99 engine for Rocketdyne's X-15 spacecraft program. Five Flo-Ball dual propellant valves are installed in each engine, providing the only control the pilot has over its operation. Photograph of the first liquid hydrogen rocket engine—Pratt & Whitney's XLR-115—shows one of the Hydromatic Flo-Ball valves used in that engine.

New Turbinautic Drive

Turbinautic gas turbine drive, introduced at the recent motor boat show in New York, has a gas producer consisting of a radial compressor and turbine with the combustor surrounding the turbine. Power turbine is located outside the boat. Locating turbine at such a distance from the gas producer is one of the innovations of the Turbinautic drive. Drive is designed to handle gas turbines up to 250 hp.

According to Alex Roskowski, President of Precision Gears and Products, "Turbinautic" is now in development stages. Company expects to have the Turbinautic and turbine engine ready for installation on a modern skiff by Spring.

Continental Developing New Turboshaft-Turboprop Unit

Continental is moving closer to the industrial gas turbine field. They are coming out with a new industrial gas turbine, 217-5A. One version will also be used as a turboprop, 217-6A. This unit is rated 500 shp, weighs 245 lb and has a specific fuel consumption of 0.67 lb per hp at full load. It is understood there are some new features in the design that will make this turbine especially suited to both its anticipated applications.

Tube Fitting for Shipboard Use

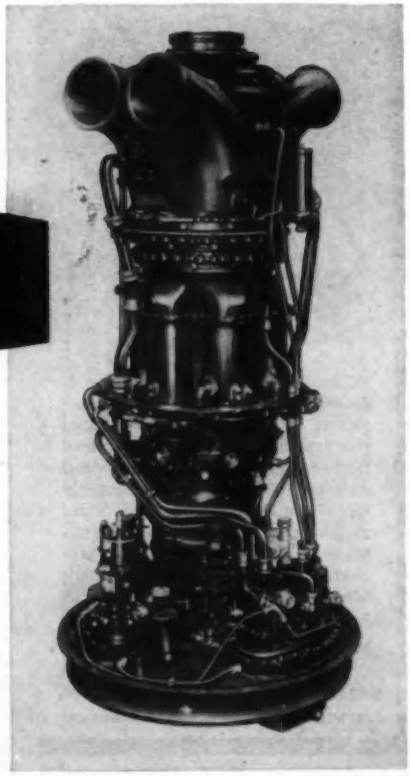
In relation to the BuShips specification MIL-F-21467 covering flareless, fluid connection fittings for use in hydraulic and air systems in Naval ships, Parker now offers the line of steel Ferulok tube fittings in a wider range of sizes.

For example, the Ferulok LHBU union is now available from ⅛" to 2" in 16 combination or reducing sizes not provided heretofore. A brochure or expanded listing is available.

- **Wide Power Range Available--860 to 2000 SHP**
- **Low Weight--830 lbs., including accessories**
- **Compactness--70 x 33½ inches, overall**
- **Passed official 150 hour type test at 1650 SHP--alone in its class**
- **Currently in production and operating in two aircraft types**

NAPIER GAZELLE

FREE TURBINE POWER PLANT FOR INDUSTRIAL APPLICATIONS



The Gazelle operates efficiently at any angle between horizontal and vertical (output shaft uppermost) . . . Either right or left-hand rotation available . . . Free-turbine design eliminates clutch . . . Either axial or radial air intakes can be fitted . . . A variety of starting systems can be used . . . Built for rugged service by Napier, precision engineers since 1808 . . .

For complete information visit the English Electric booth at the Gas Turbine Conference, Rice Hotel, Houston, March 6-10, or write to Napier Engines, Inc., 909 Dupont Circle Building, Washington 6, D.C.

NAPIER

ENGINES INCORPORATED

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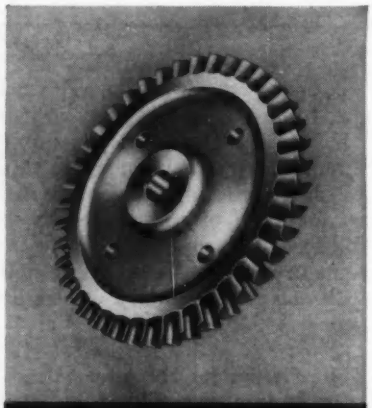
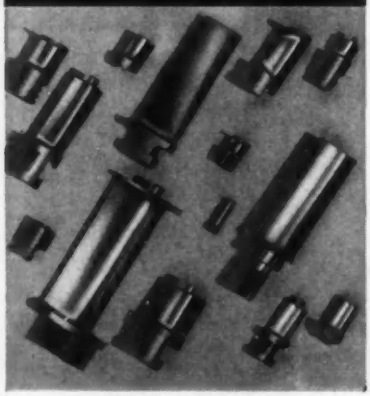


• wheels
• blades
• buckets

Schellens-True Corp.



The Schellens-True organization is devoted exclusively to the manufacture of turbine blades, wheels, vanes and nozzles of all types, machined from a wide variety of alloys and materials. We have developed entirely special automatic blade and wheel machining equipment available nowhere else. Creative engineering, precision manufacturing and rigid quality control assure a reliable product at a minimum cost.

May we quote on your requirements?

SCHELLENS-TRUE CORP.
Ivoryton Connecticut

1873B

New Capabilities for Aluminum Alloys

A patent covering an aluminum alloy that can be cast to the higher strengths necessary for advanced missile and aircraft components has been granted to North American Aviation, Inc. Composition of the alloy, which is called "Tens-50", makes it possible to produce stronger parts much easier and with less expense than is required with conventional alloys. This was announced by Pat Bales, General Manager of Navan Products, Inc., North American Aviation's invention-marketing subsidiary.

Bales said that the new alloy is now being specified for the majority of aluminum castings in the liquid rocket engines that have powered the nation's successful major missiles. Also, it is being used in many of the country's most advanced missiles and aircraft. A substantial price decrease for the alloy was also announced by Bales. "Volume use of the Tens-50 alloy makes this possible", he said.

An important feature of the new alloy's composition is addition of a small amount of beryllium. Ordinarily, during melting and pouring of metal in the casting process, iron impurities are picked up and the casting becomes brittle. In the new alloy, the iron picked up is modified by the beryllium and the casting's strength is unimpaired.

Other ingredients in the alloy also contribute to its characteristic of easily achieved quality. "Experience has shown", Bales stated, "that for comparable conditions, higher tensile strengths are possible with castings made from the Tens-50 alloy than from the high purity metal. Thus, superior foundries can use Tens-50 for lower cost, high quality production, and many more average foundries are given capability to cast parts to acceptable standards."

Leaking Seals? Maybe This Is Your Answer!

Here's a low-cost solution to sealing off those high pressure and high temperature problems. GASEALS are hollow metal rings—of mild steel, stainless, monel, cupro-nickel or copper alloy—that contain an inert gas under 600 psi. They're placed in joint faces that have been grooved to receive them—combined depth is slightly less than GASEAL diameter to give good seal and prevent excessive distortion. They're reusable . . . and are reported to give effective sealing over a wide temperature-pressure range. If you'd like to know more about this new design tool—drop us a Reader Service card today.

Micro Metallic High Flow Filter

High flow, large cake capacity and small size are features of the new STAR S-78 porous stainless steel filter element manufactured by Micro Metallic Division of Pall Corporation. STAR S-78 is contained in a stainless steel housing only 4 in. in diameter, 6 to 18-in. long. Filtration ratings down to 2 microns are available. Unit is suitable for operating pressures from full vacuum to 125 psig and operating temperatures up to 300°F. The very large surface area per unit of volume of this filter permits high flow rates and low pressure drops. For instance, the 6-in. unit can be used for flow rates up to 5 gpm or 60 cfm at pressure drops of only 2 to 3 psi. STAR S-78 is now being used with many different kinds of gas turbines. More information available—drop us a Reader Service card.

Airlines Get New Test Stand From AiResearch

First deliveries of a new test stand for commercial air turbine starters are being made to Northwest, Scandanavian Airlines System and Air-India airlines. Stands are manufactured by AiResearch Manufacturing Division of The Garrett Corporation, Phoenix, Arizona. Garrett has been building air turbine starters since 1947.

AiResearch ran a survey of existing and planned commercial airline overhaul facilities. Then they came up with their new test stand for the

airlines. It requires only a basic 17 psig, 435°F air source.

Simplicity of design was the order of the day to AiResearch design engineers. For instance, such an item as selection of wheel braking was kept pneumatic in order to keep the unit all pneumatic.

AiResearch's new test stand has both an overspeed checkout and an inertia mass pad. They've found the inertia mass principle to be the most suitable for duplicating all turbine starting loads.

Standard AND 20002 mounts, duplicating starter mounts on all present or projected commercial turbines are used to attach starters for testing. Starter run-up is accomplished by varying air pressures and temperatures as correlated by AiResearch. It's reported that no wheel or bearing changes are required. Use our handy Reader Service card for more information.

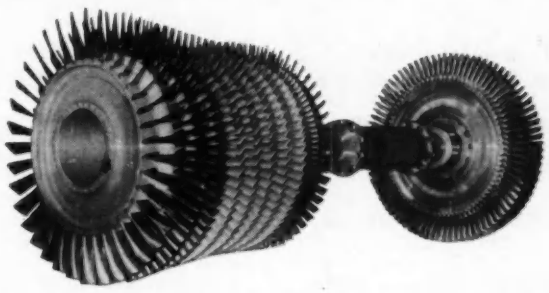
New Centrifugal Separator Purifies Jet Fuel On Carriers —Keeps Up With Daily Demands

A Special jet fuel purifier has just been developed by De Laval Separator Company for installation aboard U.S. Navy aircraft carriers. First of its size to be put into Navy service, the Model B-214 fuel purifier will remove dirt and water which might cause jet engine flameouts. Its high capacity—12,000 gal per hr on continuous operation—allows fuel processing to keep pace with normal operational needs. This minimizes storage time between the purifier and the plane, preventing condensation and accumulation of water in the fuel. Also, De Laval's purifier is reported to occupy but a fraction of the space formerly required. Similar to standard centrifugal separators used on aircraft carriers and other Navy ships for diesel oil purification. However, the Model B-214's large size did present certain special design and metallurgical problems.

U. S. Navy placed an initial $1,000,000 order with De Laval. If you'd like to learn more about this new product—simply fill out Reader Service card and drop it in the mail.

...AND NOW
INDUSTRIAL GAS TURBINES

Orenda Engines Limited—the leader in the field of gas turbine development in Canada—announces the availability of a completely self-contained gas turbine powerplant for a broad range of industrial applications and burning either gaseous or liquid fuels.



This powerplant—the gas producer rotor assembly illustrated above—is backed by

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- 6700 HP non-regenerative unit for long life and high efficiency with continuous operation in PROCESS INDUSTRIES, BLAST FURNACES, MARINE PROPULSION.
- 7000-7500 HP non-regenerative unit for intermittent and peak load duties in POWER PEAKING, STANDBY UNITS, FIREFIGHTING EQUIPMENT.

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A.S.M.E., Rice Hotel, Houston, Texas • March 6th to 9th, 1960

GT PATENTS

TURBINE WHEEL AND SHAFT ASSEMBLY (2,901,214) **2 CLAIMS** Arthur J. Slemmons, Birmingham, Michigan.

POWER PLANT SPEED AND TEMPERATURE CONTROL (2,901,885) **10 CLAIMS** Ferdinando Carlo Reggio, Norwalk, Conn.

METHOD OF INCREASING ENGINE THRUST (2,901,886) **7 CLAIMS** Mona Phyllis Doerner, Walnut Creek, California, assignor to the Dow Chemical Company, Midland, Michigan.

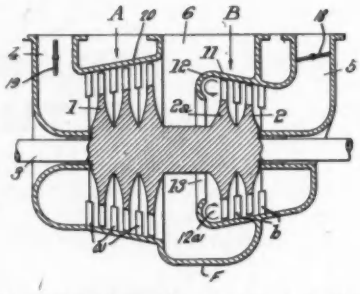
COOLING TURBINE (2,903,307) **1 CLAIM** Otto E. Balje, Hollywood, and Clyde R. Stein, Los Angeles, California, assignors by mesne assignments, to Crane Co., Chicago, Ill., a corporation of Illinois.

JET DEFLECTOR (2,903,851) **4 CLAIMS** Willy A. Fiedler, Woodland Hills, California, assignor to the United States of America as represented by the Secretary of the Navy.

AIR INTAKE CONTROL FOR JET PROPULSION UNITS (2,906.089) **1 CLAIM** Marcel Kadosch, Paris, and Jean H. Bertin, Neuilly-sur-Seine, France, assignors to Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris, France.

THREE DIMENSIONAL VARIABLE EXHAUST NOZZLE (2,914,914) **8 CLAIMS** Cornelius E. Vanderberg, Fullerton, California, assignor to North American Aviation, Inc.

GAS TURBINES WHICH ARE FOR A TIME MECHANICALLY DRIVEN IN A DIRECTION OPPOSED TO THEIR NORMAL RUNNING DIRECTION (2,902,255) **2 CLAIMS** Robert Huber, Bellevue, France, assignor to Societe d'Etudes et de Participations, Eau, Gaz, Electricite, Energie, S.A. Geneva, Switzerland. The invention concerns gas turbines, such as used for ship propulsion, that may be required to operate in a reverse direction. The il-



lustration shows the ahead turbine (1) and reversing turbine (2). Valve (19) is open to the turbine built to supply the ahead power. Note that valve (18) is shut. One or several partitions (12) are provided to prevent at least an important portion of the air pumped by the reversing turbine when rotating in a direction opposed to its normal running direction from escaping radially. This air portion is forced to rotate as shown in a chamber (12a) formed by the partitions. Rotation is lateral with respect to the turbine wheel (or of the last wheel when the turbine has several wheels) and on the side of the outlet slots of the blades.

PROPELLANT SYSTEMS FOR REACTION MOTORS (2,906,091) **13 CLAIMS** Willi Kretschner, Nobel, Ontario, Canada, assignor to Ministry of Supply, in her Majesty's Government of the United Kingdom of Great Britain and Northern Ireland, London, England.

GAS TURBINE ENGINE WITH EXHAUST HEAT RECOVERY (2,906,092) **3 CLAIMS** Jules Haltenberger, Rancho Santa Fe, California. The present invention pertains to gas turbine temperature control. The object is to provide direct heat regeneration and the lowering of the blades' temperature by exhaust gas cooling and/or by replacing the large amount of excess air by a smaller amount of exhaust gas that enters into the compressor.

FUEL FEED AND POWER CONTROL DEVICE FOR COMBUSTION ENGINES (2,906,093) **10 CLAIMS** Lester L. Robinson, Anderson, Ind., assignor to Bendix Aviation Corporation, South Bend, Ind.

FUEL AND RAPID IGNITION APPARATUS FOR IGNITION OF FUEL IN RAMJETS AND ROCKETS (2,906,094) **3 CLAIMS** Glenn H. Damon, Pittsburgh, and John Ribovich, Mckeesport, Pa.

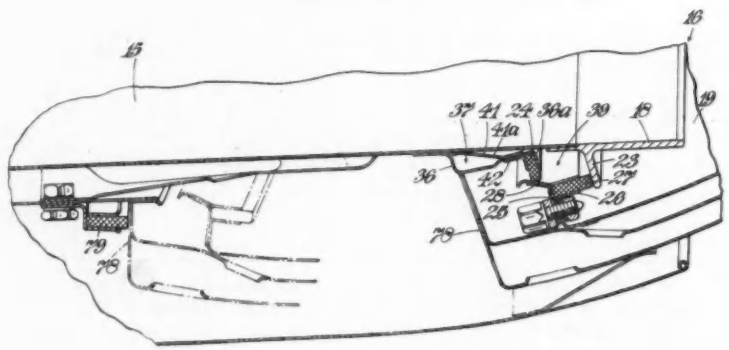
SHAFT REVOLVING APPARATUS, PARTICULARLY FOR TURBINE GENERATORS (2,914,908) **14 CLAIMS** Hans Memmel, Mulhelm (Ruhr), Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany.

PROPYL NITRATE MONOFUEL AND METHOD OF USE WITH NICKEL SALTS (2,914,910) **14 CLAIMS** Charles H. King, Jr., Manchester, Conn., assignor to United Aircraft Corporation, East Hartford, Conn.

COMBUSTION SYSTEM FOR THERMAL POWERPLANT (2,914,912) **3 CLAIMS** Edward Woll, Wenham, Mass., assignor to General Electric Co., a corporation of New York.

RADIANTLY COOLED INLET (2,914,915) **5 CLAIMS** Edward A. Sziklas and Conrad M. Banas, Manchester, Conn., assignors to United Aircraft Corporation, East Hartford, Conn.

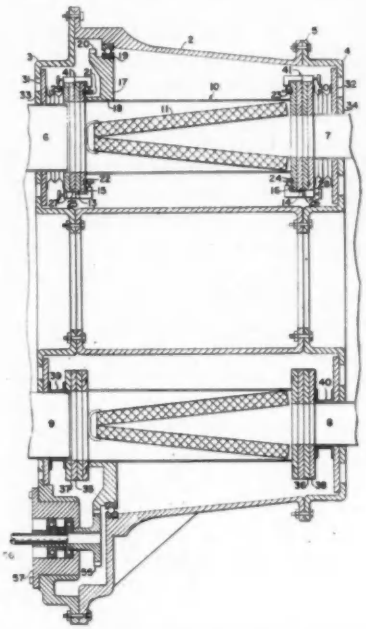
ARRANGEMENT FOR CONTROLLING THE FLOW OF A FLUID BY MEANS OF AN AUXILIARY FLOW (2,914,916) **2 CLAIMS** Paul Gelin, Neuilly-sur-Seine, and Marcel Kadosch, Paris, France, assignors to Societe Nationale d'Etude et de Construction de Moteurs d'Aviation Paris, France.



VARIABLE AREA JET NOZZLE FOR JET PROPULSION ENGINES (2,906,090) **16 CLAIMS.** Frederick William Walton Morley, Castle Donington and Peter Redfern, Littleover, England, assignors to Rolls-Royce Limited, Derby, England. According to this invention, adjustable nozzle elements are provided for varying the effective outlet area of the jet nozzle. There is a gas sealing device comprising a pair of mechanical seals operating between each adjustable nozzle element and the fixed nozzle portion. Note that the adjustable nozzle element (78), shown in solid lines, closes the area of the jet nozzle to the maximum while the dotted lines show the adjustable elements moved to the non-effective position.

APPARATUS AND METHOD FOR JET PROPULSION THROUGH WATER BY USE OF WATER REACTIVE PROPELLANT (2,914,913) **40 CLAIMS** Fred Zwicky, Pasadena, California, assignor, by mesne assignments, to Aerojet-General Corporation, Cincinnati, Ohio, a corporation of Ohio.

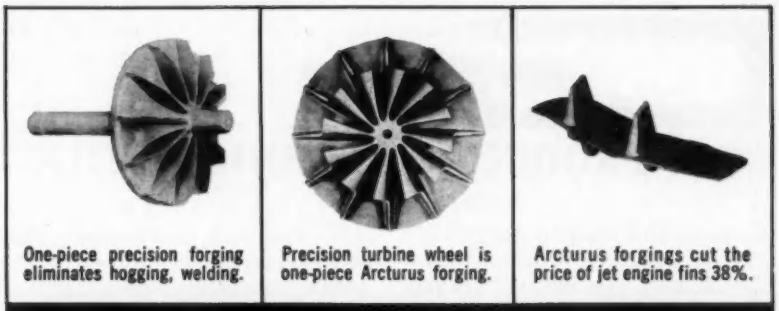
ROTARY REGENERATOR SEALS (2,902,267) **4 CLAIMS** Donald G. Rich, Syracuse, N.Y., assignor to Carrier Corporation, Syracuse, N.Y. This invention relates to seals and particularly those between the rotor and enclosing housing in rotary regenerators. Units of this type rotate about an axis and pass alternately through two gas streams (intake air and



exhaust gases) at different temperatures and pressures. A portion of the rotating medium or matrix passes through the warm exhaust gas stream that is at low pressure and then into the cold high-pressure gas stream (compressed intake air). Heat absorbed by the matrix is then given up to the cold air stream, reducing the amount of heat imput (fuel) required. This invention provides a seal that will keep gas leakage past the matrix to a minimum. The sectional view shows the application of this invention.

CONTROL OF HEAT SUPPLY TO HEAT RECOVERY BOILER OF REGENERATIVE CYCLE GAS TURBINE POWERPLANT (2,914,917) **13 CLAIMS** Francis H. Van Nest, Schenectady, N.Y., assignor to General Electric Co.

(Continued on page 48)



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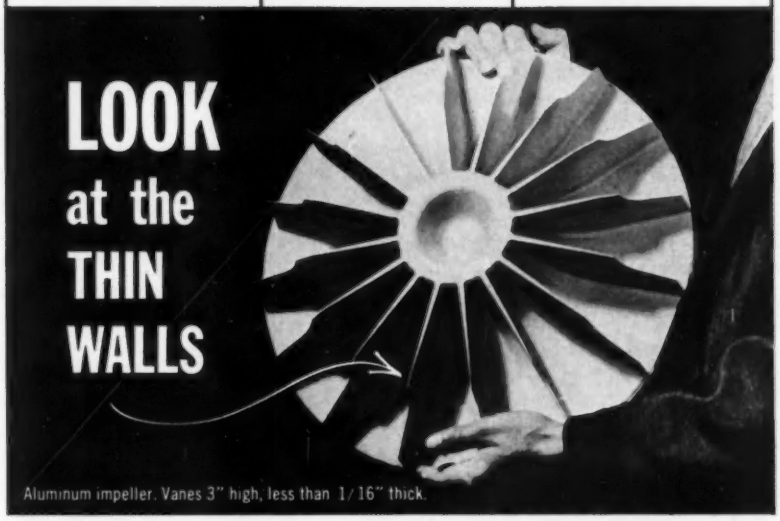
Precision turbine wheel is one-piece Arcturus forging.

Arcturus forgings cut the price of jet engine fins 38%.



Aluminum impeller. Vanes 3" high, less than 1/16" thick.

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GT PRODUCT TECHNICAL FILE

Arcturus Has Forging Bulletin

With today's emphasis on "how-to-make", a 4-page bulletin available from Arcturus Manufacturing Company will be of interest to those concerned with gas turbine production. Arcturus describes and illustrates their forging operations, showing some of the special and intricate parts made. Many are gas turbine components. Use the Reader Service Card for your copy.

"Superalloys By Vacuum Induction Melting"

That's the title of an excellent 36-page brochure from the Metals Division, Kelsey-Hayes Company. Tells you just about everything you'll need to know to have a working knowledge of the complex process which produces today's new alloys. Also has section on super alloy applications and comparison charts that quickly give you an idea of how vacuum induction alloys stack up with conventional high temperature alloys. How to get a personal copy? Just jot it down on the Reader Service Card.

"Jet Fuels— Past, Present And Near Future."

That's the subject of SAE Paper 114A, by W. S. Mount of Mobil Oil Company's Aviation Department. It was presented last month in Detroit, Michigan.

Right now, according to Mr. Mount, the free world is using 600,000 barrels per day of jet fuel. That's twice the amount of gasoline (300,000) used in aviation piston engines each day!

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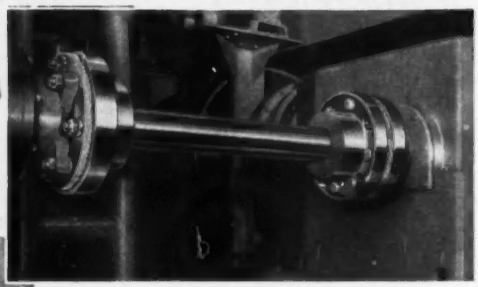

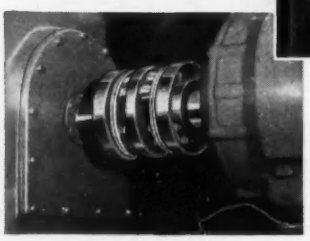

Thomas' 40 years of flexible coupling experience is at your disposal to help you meet ordinary applications or special variations for unusual cases.

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WARREN, PENNSYLVANIA, U.S.A.

Allegheny Ludlum

A new booklet on stainless steel tubing is now being distributed by Allegheny Ludlum Steel Corporation, a leading producer of stainless steels. The new 34-page booklet with 25 tables gives details on the various sizes, grades, design data, corrosion resistance, and other information valuable to industries interested in both welded and seamless stainless steel tubing. A copy for you? Use our Reader Service card.

Bendix Poroloy Filter Technical Bulletin For Your Files

A new 6-page, two-color technical brochure on Poroloy wound wire porous metal for filtration and non-filtration applications is now available from Bendix Filter Division, Bendix Aviation Corporation. This brochure details the capabilities and typical examples of wound wire porous metal with photographs, drawings and curves. Descriptive examples include stainless steel and super alloy Poroloy and low-cost Poroloy CS which is made from low alloy and carbon steels. Technical data is presented in the form of specifications and curves for flow rate and physical characteristics. Get yourself a copy—use Reader Service card.

Multi-Purpose Bendix Two-Micron Filter

Here's another one—a new two-page, two-color catalog sheet describing Model 2670 two-micron fluid filter combination for hydraulic fluids, fuels, lubricating oils, air, gases and solvents is now available from Bendix Filter Division, Bendix Aviation Corporation. Included is a detailed description and full specifications of the unit, which is designed primarily for missile/aircraft support equipment and precision industrial laboratory and process applications. Catalog sheet is illustrated with photograph, flow rate curves and dimensional line drawings.

Report on Aramco's Saudi Arabia Project

Clark Equipment Company's Bulletin 183 presents a report on Arabian American Oil Company's new gas injection project in 'Ain Dar, Saudi Arabia. Written by John W. Barker of Aramco, the article describes this $30,000,000 project which will gather and inject 210,000,000 cu ft of gas per day in the Ghawar field.

All details of the operations are covered, including the use of five series-connected Clark gas turbines for compressor drive as well as description of use of an additional turbine to drive a 5600-kw generator to power the gas-oil separator plants.

English Electric's New Turbines Detailed

Publication GT/103 from English Electric Company describes in considerable detail in its 24 pages the new EM27 gas turbines, rated 2300 to 3000 bhp. It shows various installations of these turbines together with cross-sections, performance curves and a rather detailed description of component parts. An installation diagram is included, showing the area and cu ft required. This unit is available in both simple cycle and with heat exchanger. Copy of this publication is yours—use Reader Service card.

New Bulletins From Solar Aircraft

Bulletin T-12M describes the Mars 50 hp, 100 lb turbine used for operating generators, water pumps as well as many other applications.

Bulletin T-12T describes the Titan 55 to 80 hp, 52 to 90 lb turbine used for operating generators and accessories. Titan is also used for very light aircraft due to having a free power turbine.

Bulletin T-12J describes the Jupiter 600 hp, 1000 lb turbine used for generator drive, marine and other applications.

Still another bulletin describes the Saturn 1250 hp, 95 lb turbine. This one is used where a more powerful turbine is required. Copies for you? Jot them down on Reader Service card.

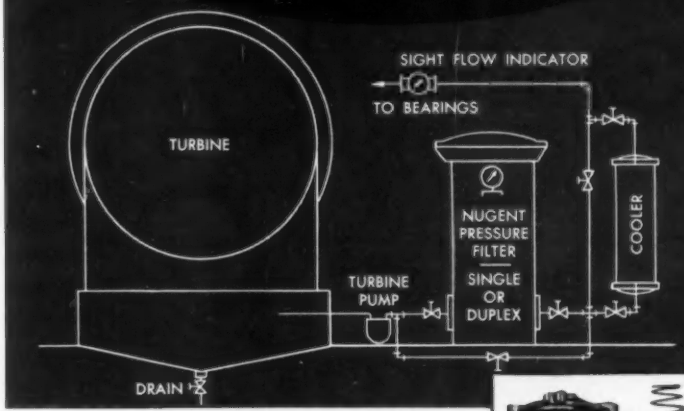
Micro Porous Stainless Steel Filters

New, revised literature on porous stainless steel filters is available from Micro Metallic Division of Pall Corporation. Full specifications are included on standard filters manufactured by the company. Plus there's a number of new filter types and sizes presented. Detailed technical data is included to permit direct ordering of stock units. Use Reader Service card for your personal copy.

Fluid Coupling Bulletins Available From Twin Disc

Twin Disc Clutch Company's new bulletin describes their small aluminum-type, 7.4S to 10.6 fluid couplings. Large stamped steel-type, 12.2 to 27 are also covered. Capacities from ¾ to 850 hp. Twin Disc's fluid PTO combines a fluid coupling with bell housing, bearings and output shaft. Interested? Use Reader Service card.

LUBRICATING OIL FILTERING SYSTEMS for GAS TURBINES



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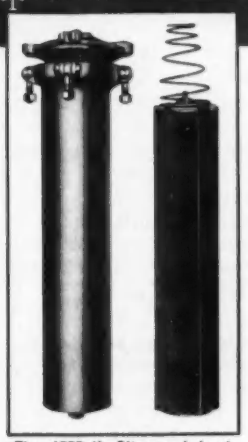

Fig. 1555-4L filter and laminated disc cartridge provide excellent micronic efficiency.

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TECHNICAL BRIEFS

Gas Turbines, Installation and Operational Problems and Performance Evaluation by Charles Bultzo, Senior Mechanical Engineer, Technical Division, Humble Oil and Refining Company, Baytown, Texas. (No. 59-PET-9, Petroleum Division, ASME, Houston, Texas, September 20-23, 1959)

"To date, the gas turbine has proven itself capable of high reliability and availability. Design changes and additional shop testing are improving these factors. Still facing the user are the recurring problems encountered during start-up and operation.

"The equipment covered by this paper is a simple-cycle, 2-shaft, 5000-hp gas turbine. The turbine drives a high-capacity centrifugal blower supplying regenerator air to a fluid catalytic-cracking unit. For maximum overall thermal efficiency, the hot exhaust gases are combined with the regenerator air after it leaves the process unit to generate 600-psig steam by burning the CO in the combined stream."

The paper then gives a detailed mathematical heat balance of the gas turbine and a discussion of the improvement of efficiencies in the component parts.

Considerations For the Reduction Of Noise In Ship Installations of Gas Turbines by Edward M. Herrmann, Head, Auxiliary Equipment and Components Division, U. S. Naval Engineering Experiment Station, Annapolis, Md. (No. 59-A-238, Gas Turbine Power Div., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

General noise-reduction considerations for shipboard installation of gas turbines are discussed. Specific information relating to sound-absorption materials, duct treatments, structure-borne sound isolation, and air-borne sound insulation is graphically presented.

Relative Thermal Performance Of Carbon Dioxide And Helium In Nuclear-Power Cycles—by Frank E. Tippets, Atomic Power Equipment Dept., General Electric Co., San Jose, Calif. (59-GTP-14 ASME, Gas Turbine Power Conference, Cincinnati, Ohio, March 8-11, 1959)

Interest in the gas-cooled power-reactor concept has raised questions regarding relative merits of various gases as heat-transfer and thermodynamic working fluids in nuclear-power cycles. For various reasons of availability, chemical behavior, and thermodynamic characteristics, perhaps the most likely choice is among carbon dioxide, nitrogen, and helium. Both the gas-cooled reactor-steam turbine system (indirect cycle) and the gas-cooled reactor—gas turbine system (direct cycle) are considered. A limited comparison of reactor heat-transfer-surface-area requirements is also made between the indirect cycle and direct cycle for both carbon dioxide and helium.

25,000-KW Mene Grande Gas Turbine Installation—by C. M. Honaker, Mene Grande Oil Company, Barcelona, Venezuela and D. F. Bruce, Industrial Gas Turbine Engineering, Westinghouse Electric Corp., Lester Branch, Philadelphia, Pa. (59-A-191, Gas Turbine Power Division, ASME Annual Meeting, Atlantic City, N. J., November 29-December 4, 1959)

This plant has 5 Westinghouse Model W-819 gas turbines rated 5000 kw each. Operating experience acquired in the installation of a central power system is given with reference to original design objectives and evaluation as regards accomplishment.

Marine And Mobile Applications Of Industrial Gas Turbines—by E. O. Kohn, Assistant Chief Engineer, Turbine Department, Ruston and Hornsby Limited, Lincoln, England. (59-A-295, Gas Turbine Power Division, ASME Annual Meeting, Atlantic City, N. J., November 29-December 4, 1959)

The paper deals mainly with service experience on a deck-mounted installation of a standard industrial 1260-hp gas turbine and shows how the type of installation evolved has been adapted for general mobile applications. Also, a description is given of a new 430-hp industrial unit, designed with marine requirements in mind. Application of its design concepts to a new class of turbine is briefly touched upon.

Development And Sea Trials Of Marine Proteus Engines For Brave Class Fast Patrol Boats—by B. G. Markham, Engineer in Charge of Industrial and Marine Gas Turbines, Bristol Siddeley Engines Limited, Filton, Bristol, England. (59-A-273, Gas Turbine Power Division, ASME Annual Meeting, Atlantic City, N. J., November 29-December 4, 1959)

This important paper describes adaptation of an aircraft gas turbine for marine use, shore-testing under simulated marine conditions and sea trials. Design of the air-intake and the exhaust arrangements, along with many other details are also discussed in easily-understood language.

Development Of A 3500-HP Marine Gas Turbine—by D. W. Knowles, Chief Engineer—Gas Turbines, Utica Division, Curtiss-Wright Corporation, Utica, Mich. (59-A-199, Gas Turbine Power Division, ASME Annual Meeting, Atlantic City, N. J., November 29-December 4, 1959)

In 1954, Bureau of Ships, USN, established a requirement for a modern gas-turbine propulsion power plant incorporating the results of recent advances in the state of the turbine art. The 40MV59UB-1 engine described in this paper is the outcome of a development program initiated to meet the Navy's needs. The engine has been developed to a sea-level, standard 60°F day rating of 3700 hp with a specific fuel consumption of 0.58 lb/shp-hr. In emergencies, 3900 hp may be used. Engine weighs 7000 lb giving a specific weight of 2 lb/per hp. Unit consists of an 8-stage axial compressor driven by a 2-stage turbine which acts as the gas generator for a 3-stage free-power turbine having a maximum speed of 5900 rpm. The gas generator is fired by six can-type combustors which burn Navy diesel fuel.

The Film Vaporization Principle For Gas Turbine Combustors is the subject of a report to the Office of Naval Research, signed by G. W. Maybach and A. W. Hussmann of The Pennsylvania State University.

This Report refers to actual tests which indicate that the film vaporization principle for combustion works in a combustor in a manner similar to that demonstrated in diesel engine combustion systems, notably MAN's M-system as incorporated in their "Whisper" engine.

Relation Of Fuel Properties To Combustion Cleanliness In A Small Gas Turbine Engine—by M. J. Boegel and J. F. Wagner, Automotive Engineering Division, Gulf Research & Development Company, Pittsburgh, Pennsylvania. (No. 1146, SAE Annual Meeting, Detroit, Mich. January 11-15, 1960)

Experience shows that while the gas turbine engine is much less critical to fuel properties than is the piston engine, its fuel appetite does require limitations on many fuel properties. This paper is concerned only with those properties that affect combustion cleanliness, *i.e.*, combustor deposits and exhaust smoke. The Boeing 502-10C engine was selected for this program because at the time these studies were initiated this engine appeared to be most typical of the small turbine engines available for automotive applications.

(*Continued on page 47*)

TECHNICAL BRIEFS . . .

(Continued from page 44)

NASA Research Bearing On Jet Engine Reliability—by S. S. Manson, NASA Lewis Research Center, S. M. Ault, NASA Lewis Research Center and B. Pinkel, Rand Corporation. (No. 49T, SAE National Aeronautic Meeting, New York, N. Y., March 31-April 3, 1959)

Turbojet engine reliability has long been an intense interest to military users of this type of aircraft propulsion. With recent inauguration of commercial jet transport, this subject has assumed a new dimension of importance and this paper is an excellent contribution to the subject. It highlights results of extensive studies of factors affecting operational reliability and indicates further areas for study.

The Gas Turbine Impact On The Petroleum Industry—by G. W. Ferguson, Technologist, Research & Technical Department, Texaco Inc., Los Angeles 5, Calif. (From a paper presented at the 1959 Fifth World Petroleum Congress)

Advances being made in development and application of gas turbines are briefly reviewed, together with a look at the possible course future developments may take. Information on fuel and lubricant requirements for military and commercial aviation gas turbines is given, including specification data and inspection tests on representative fuels. Application of gas turbines for industrial, railroad, marine and automotive purposes and their petroleum requirements are also discussed.

Sliding On Air—By Alex L. Haynes, Director, Engineering Research and Advanced Product Study Office, Ford Motor Company; and David J. Jay, Principal Research Engineering Associate, Levacar Project, Ford Motor Company. (No. 1338, SAE Annual Meeting, Detroit, Mich. January 11-15, 1960)

Ford's "Levacar" concept of high-speed vehicles "sliding on air" is discussed. Unlike other "air cushion types", the vehicle will be supported on what is described as "tissue-thin" air film separating slippers or "levapads" from the supporting surface. According to the paper, some form of gas turbine propulsion will be required.

Radiation From Flames In Gas Turbine Combustor—by R. M. Schirmer and L. A. McReynolds, Research Division, Phillips Petroleum Company, Bartlesville, Okla. and J. A. Daley, Aeronautical Engine Laboratory, Naval Air Material Center, Philadelphia, Pa. (No. 1148, SAE Annual Meeting, Detroit, Mich. January 11-15, 1960)

This paper points out that radiant heating of metal parts was shown to be a function of their location in the combustor because quenched combustion products can effectively absorb, or "screen-out", flame radiation. Effect of monocycle versus polycyclic aromatic components in JP-5 fuels (same ASTM Smoke Points) on total flame radiant energy was investigated. Performance of research combustors and a J79 aircraft gas turbine engine single combustor operated at low (atmospheric) pressure showed variations in aromatic type or content within present JP-5 specification to have no significant effect on flame radiation. Performance of research combustors and a J57 aircraft gas turbine engine single combustor operated at high (5 to 15 atmospheres) pressure showed that polycyclic aromatic fuel blends burn with higher flame emissivities than monocyclic aromatic fuel blends of comparable ASTM Smoke Point.

(Continued on page 50)

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INDUSTRY NEWS . . .

(Continued from page 12)

French Police Planes Turbo-Prop Powered

Colonial Police planes have improved performance as the result of newly-fitted turbine engines. Planes are the Morane-Saulnier 1500 Epervier; engines are 700-eshp Turbomeca Bastan units driving 3-bladed propellers. Prototype Epervier plane was powered by a 386-eshp Turbomeca Marcadau turbine and 2-bladed propeller. Added power with little change in weight has greatly improved the plane's performance.

French "Alouettes" in Demand

West Germany has signed a contract with Sud-Aviation for delivery of 130 "Alouette II" turbo-helicopters to equip that country's ground forces. Total orders for this French craft (built in 17 different countries) are approaching the 500 mark. And to use an expression—that's a lot of turbine-driven helicopters.

Light-Weight Gas Turbine Powers One-Man 'Copter

Solar Aircraft Company's 52-lb "Titan" gas turbine passed exacting tests in a one-man helicopter. This "Titan" turbine is built in both constant-speed and variable-speed configurations. This tiny turbine can provide rugged power for almost any application where small size, dependability and greater power are important.

It is especially suitable as a power source for portable, hand-cranked electric generators. Proven-in-service Solar gas turbines—ranging from 50 to 1100 hp—are creating new standards of performance and reliability in dozens of military and commercial applications.

Ground Support Order

AiResearch has just received a U.S. Navy contract for 286 small gas turbines. They'll be used for pneumatic starts of Navy's jets.

General Electric Jet Development

General Electric's Jet Engine Department here today announced receipt of a $10.8 million contract let by the Air Material Command's Aeronautical Systems Center. This contract covers further development work on the Company's J93 turbojet engine which is the scheduled powerplant for the North American Aviation B-70 Mach 3 advanced bomber.

New Kaman Helicopter Order

Kaman Aircraft has received a $14 million contract for additional production of HU2K-1 helicopters. The HU2K-1 is powered by a General Electric T-58 gas turbine engine and carries the latest in automatic and electronic autopilot and navigation equipment. The HU2K-1 helicopter was developed to meet the Navy's need for a high speed, all-weather helicopter. It's designed to accomplish a variety of missions.

PATENTS . . .

(Continued from page 41)

IMPROVED STRUT-SUPPORTED TURBINE BLADE (2,894,719) 2 claims Douglas V. Foster, Kansas City, Mo., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy.

RECYCLING METHOD OF OPERATING FOR POWER PLANTS (2,895,291) 3 claims Frank M. Lewis, Weston, and Joseph H. Keenan, Belmont, Mass., and Kurt Goldman, Hamilton, Ohio, assignors, by mesne assignments, to Baldwin-Lima-Hamilton Corp.

CONTROL SYSTEMS FOR GAS TURBINE INSTALLATIONS (2,895,294) 2 claims Basil Joseph Terrell, Monkseaton, England, assignor to the Parsons and Marine Engineering Turbine Research and Development Association, Wallsend, England.

GAS TURBINE POWER PLANT WITH REGENERATOR (2,895,296) 6 claims Waldemar Hryniszak, Cullercoats, Whitley Bay, England, assignor to C. A. Parsons & Company Limited, Newcastle-upon-Tyne, England.

TURBOJET CONVERTIBLE TO A RAMJET (2,896,408) 5 claims William J. O'Donnell, Freeport, N. Y., assignor to Republic Aviation Corporation, Farmingdale, N. Y.

COMBUSTION APPARATUS FOR BURNING ASH-FORMING LIQUID FUEL (2,895,297) 8 claims John Alan Gardiner, Crookham, near Aldershot, England, assignor to Power Jets (Research and Development) Limited, London, England.

ARRANGEMENTS FOR CONTROLLING THE EFFECTIVE THRUST PRODUCED BY REACTION-PROPULSION UNITS AND IN PARTICULAR BY RAM-JET UNITS OR ATHODYDS (2,914,911) 2 CLAIMS Gerhard Richter, Decize, Nievre, France, assignor to Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris, France.

COMBINATION EXHAUST CASING AND SHAFT SUPPORT FOR A TURBINE (2,914,919) 11 CLAIMS Louis Ernest Varadi, Danvers, Mass., assignor to General Electric Company.

ROTARY JET ENGINE (2,914,920) 6 CLAIMS Erasmus J. Paradiso, Valley Stream, N. Y.

ROTATING FLAME SPREADER FOR STATIONARY FLAME-HOLDER (2,914,921) 6 CLAIMS Walter D. Pouchot, Prairie Village, Kansas, assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa.

TURBINE COOLING AIR METERING SYSTEM (2,896,906) 1 claim William J. Durkin, Johnson County, Kansas, assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy.

AIR-COOLED BLADE (2,896,907) 1 claim John C. Fresche, Fairview Park, Ohio, assignor to the United States of America as represented by the Secretary of the Navy.

IGNITER (2,897,649) 6 claims Robert Reddy, Pasadena, Calif., assignor to the United States of America as represented by the Secretary of the Air Force.

GAS TURBINE JET ENGINE STARTER WITH SERIALLY-CONNECTED CONCENTRICALLY-ARRANGED COMBUSTION CHAMBERS (2,914,918) 18 CLAIMS Leo I. Kaplan, Sunland, California, assignor to Poly Industries, Inc.

TURBOCHARGER FOR INTERNAL COMBUSTION ENGINES (2,899,797) 8 claims Rudolph Birmann, Newtown, Pa., assignor to De Laval Steam Turbine Company, Trenton, N. J.

COMBUSTION GAS PRODUCING DEVICE (799,675) 7 claims United Aircraft Corporation, 400 Main St., East Hartford, Conn.

CONTRACTS • PROCUREMENTS . . .

(Continued from page 12)

15. Oklahoma City Air Material Area, USAF, Tinker A. F. Base, Okla. "Overhaul, Modification, Repair and Test of Compressor, Turbine and Regulator Assemblies. (RFP OC-0-03F-0021)"—Job—$232,963—The Garrett Corp., AiResearch Mfg. Div., Los Angeles 45, Calif.

16. AMC Aeronautical Systems Center, USAF, Wright-Patterson A. F. Base, Ohio. "42 each Starters, Pneumatic, Aircraft Engine, Type MB-6, in a/w Exhibit WCL-1046, dtd 14 Nov. 55, Contractor's Spec. No. HS-1552C dtd 15 May 1958, P/N 518784, Aerno 42-9407, and data. For: Use on F-104D Aircraft. (PR EA-9-03J-4841)"—$40,656—United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn. This was a competitively negotiated procurement. Two bidders were solicited and 2 proposals were received.

17. Hq. Oklahoma City Air Material Area, USAF, Tinker A. F. Base, Okla. "Overhaul, Repair and Modification of Reduction Gears for T-55 Engines. (RFP OCPNA-13-60)"—Job—$282,573—Allison Division, General Motors Corp., Indianapolis 6, Ind.

18. Bureau of Aeronautics, Department of the Navy, Washington 25, D. C. "Services and materials for performing an analytical overhaul and repair program on Government-owned Model J-34-WE-46 engine accessories. NOas 60-0169-f (MA-33-388-59)"—$213,-002—Westinghouse Electric Corp., Washington 6, D. C.

19. Oklahoma City Air Material Area, USAF, Tinker AF Base, Okla. "Overhaul, repair and/or modification of Turbine Wheel and Shaft Assemblies, Compressor and Rotor-Assemblies (IFB 34-601-60-11)"—Job—$40,108—Allison Division, General Motors Corp., Indianapolis 6, Ind.

20. Oklahoma City Air Material Area, USAF, Tinker A. F. Base, Okla. "Overhaul and modification of forty (40) Air Turbine Motors. (RFP OC-0-031-2-0018)"—Job—$66,158—The Garrett Corp., AiResearch Mfg. Div., Phoenix, Arizona.

21. Oklahoma City Air Material Area, USAF, Tinker A. F. Base, Okla. "Overhaul, repair and modification of 70,000 Turbine Buckets for J-33 Engines. (RFP OCPNA-12-60)"—Job—$193,000—Allison Div., General Motors Corp., Indianapolis 6, Ind.

22. AMC Aeronautical Systems Center, USAF, Wright-Patterson A. F. Base, Ohio. "YT55-L-5 Shaft-Turbine Aircraft Engines; Preliminary Manuals, Spare Parts, Assemblies and Accessories, Special Tools and Ground Handling Equipment, and Training. (For Use on Army YHC-1B Helicopters) (PR's 57169; 62427; 96753)"—$1,608,000—AVCO Corp., Lycoming Div., Stratford, Conn.

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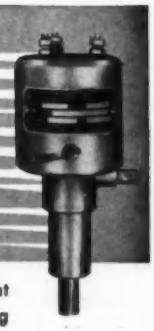

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TECHNICAL BRIEFS . . .

(Continued from page 47)

Developing Reliability in the T58 Engine Control by Richard H. Rosenberg, Supervisor—Advanced Control Design, General Electric Company, SAED, Lynn, Mass., (No. 59-A-291, Aviation and Gas Turbine Power Divns., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

The 1050-shp T58 gas-turbine engine utilizes a "free" turbine, not mechanically connected to the gas generator, to supply output power. The gas generator is a simple jet engine that's exhaust flows through the free turbine to produce torque.

Main control for the T58 is a hydromechanical unit built by the Hamilton Standard Division of the United Aircraft Corporation. To minimize pilot effort in helicopter installations and provide ready adaptability to other loads, a free turbine and therefore load-speed-governing design was chosen, with appropriate gas-generator protective schedules.

The control receives a signal of desired free-turbine speed through a pilot-operated lever, compares this to actual speed sensed by a flyball governor through a flexible drive shaft from the free turbine, and adjusts gas-generator speed automatically to maintain desired free-turbine speed. Droop governing is employed, meaning that small changes in steady-state free-turbine speed are associated with large changes in steady-state power output. This provides easy stabilizing and automatic load-sharing.

Many minor changes and features were discussed such as use of flapper servos instead of trapped-volume servos, use of a slower but more reliable indicator of compressor inlet temperature, and other control features. In conclusion the paper stated that a thoroughly-proven control has been developed for the T58 with a modest direct expense.

Design And Development Of A Convective Air-Cooled Turbine and Test Facility by W. F. Weatherwax, Engineer, Turbine Aerodynamics Unit, Small Aircraft Engine Department, Flight Propulsion Division, General Electric Company, Lynn, Mass. (No. 59-A-282, Gas Turbine Power Div., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

Objectives of the development program reported in this paper are:

1. Development of a fully convective air-cooled flight-type, single-stage turbine to demonstrate feasability of operation at an average inlet temperature of 2000° F, with 4.3% of compressor discharge cooling air.
2. Development of a test facility.

From testing to date, the following conclusions are made:

1. The test facility has been de-bugged and developed sufficiently to allow high-temperature testing for mechanical reliability and cooling effectiveness. In addition, low-temperature aero-thermodynamic testing can be done.
2. To date, test results have shown no evidence of inadequate cooling with design cooling flows.
3. More endurance testing is needed to establish mechanical reliability.
4. Rotating instrumentation yielded useful information on bucket strut temperatures.
5. There is no evidence of cooling-passage clogging.
6. Design procedure is adequate and will be used again for future designs.
7. Manufacturing and inspection techniques, developed during this program, make possible low-cost production of this type blading.

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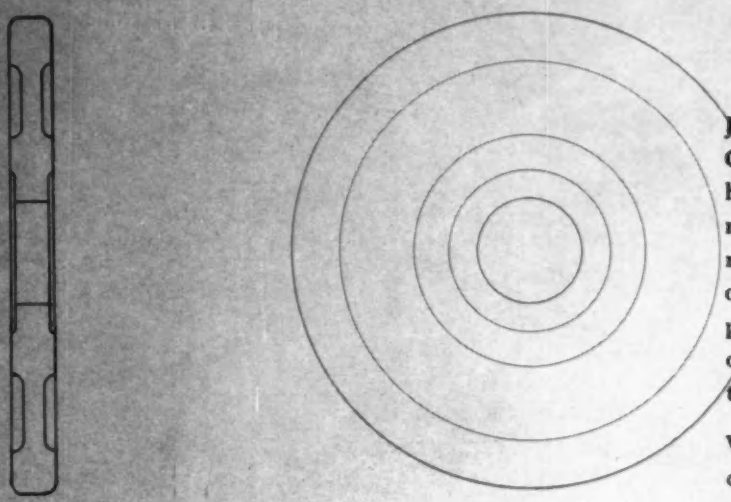
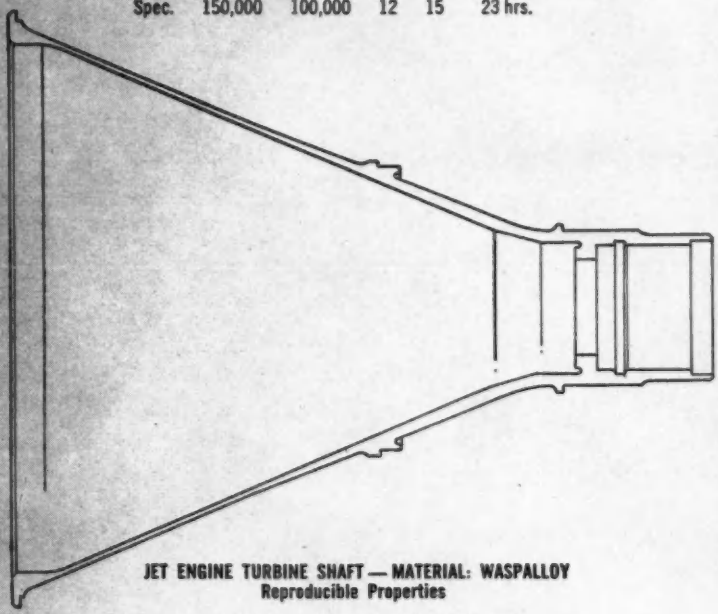


JET ENGINE TURBINE DISC — MATERIAL: INCO 901

	T.S.	Y.S. .2%	E.L.	R.A.	S.R. 1200° F. 80,000 lb./sq. in.
	175,000	128,000	20	23	225 hrs.
Spec.	150,000	100,000	12	15	23 hrs.



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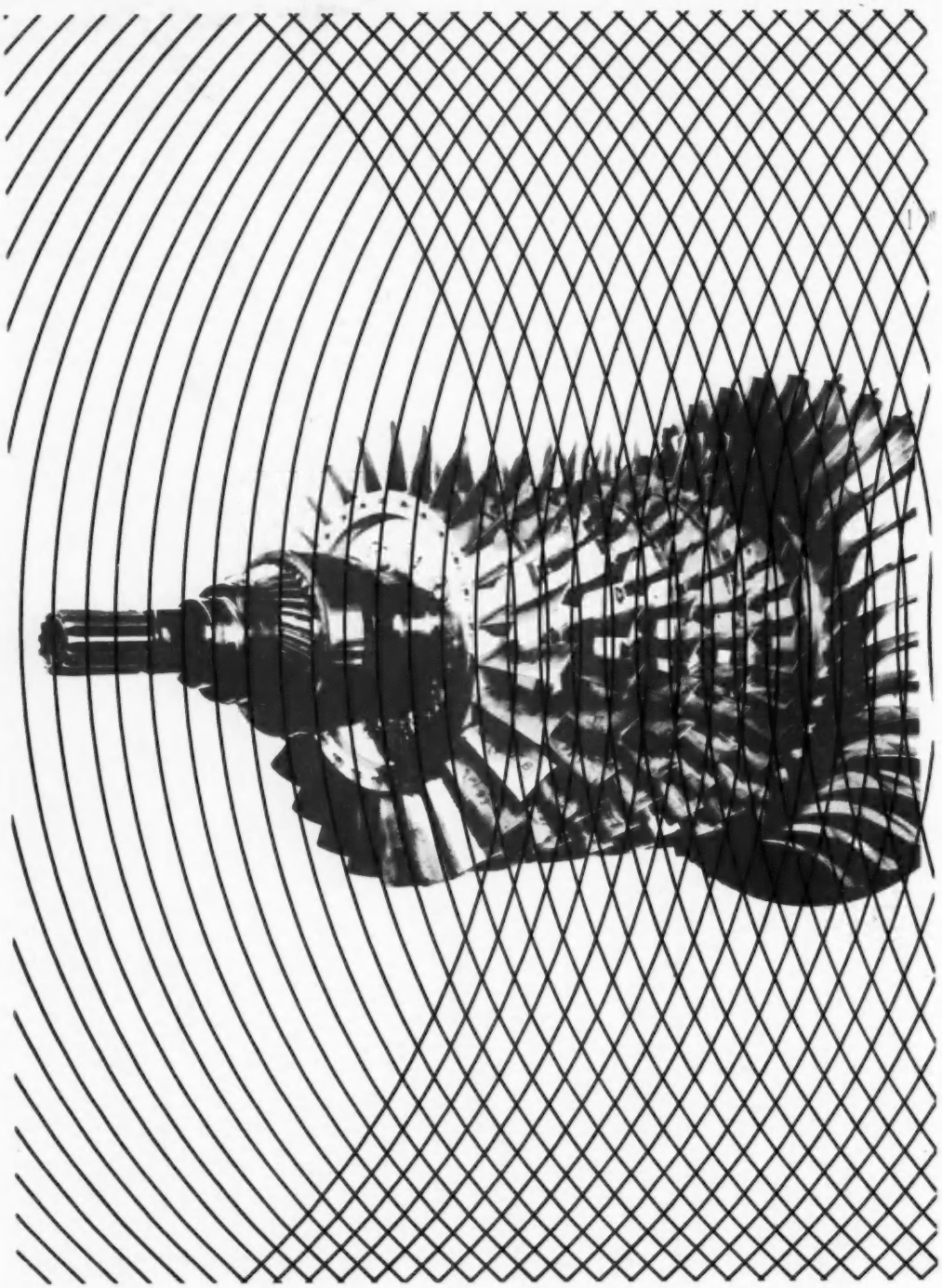

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